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Classification of the CALIFORNIA DESERT for GEOLOGY-ENERGY-MINERAL RESOURCE POTENTIAL

A Geostatistical Classification

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CLASSIFICATION OF THE CALIFORNIA DESERT FOR GEOLOGY - ENERGY - MINERAL RESOURCE POTENTIAL GEOSTATISTICAL CLASSIFICATION

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ABSTRACT

Lands in the California Desert Conservation Area (CDCA)* were classified according to their potential for geology - energy - mineral (G - E - M) resources using geostatistical techniques and an expert panel. The CDCA comprises over 100,000 square kilometers in southeastern California. All available reports of G - E - M occurrences in the CDCA were collected. Data on the 3,146 occurrences include location, commodity, name and, in some cases, geologic environment and production history. Forty geological variables represented on the Geologic Map of California; one geophysical variable (Bouguer gravity) and 20 lineament variables from each of four sources (LANDSAT imagery, Bouguer gravity contours, and aerial and Skylab photography) were recorded on a cell - by - cell basis over the entire CDCA. Data were encoded in numerical form for 26,810 cells (each 2 km by 2 km square). Three tonal anomaly variables and 30 geochemical variables were also recorded on a cell - by - cell basis for subareas of the CDCA where these data are available. Data recorded in this fashion, plus the data on G - E - M occurrences, served as the basis for statistically classifying cells according to likelihood of mineral occurrence. Cells so classified are 4 km by 4 km (an aggregate of four of the smaller 2 km x 2 km cells). Gamma - ray spectrometric (bismuth, thallium, potassium, bismuth to thallium ratio) and aeromagnetic data were also recorded on a cell - by - cell basis for use by the expert panel. Discriminant function analysis (DFA) is the statistical method used to classify the cells. The cells of the CDCA are classified with respect to the potential for gold deposits; iron deposits; manganese deposits; tungsten deposits; combined copper, zinc, lead, and silver deposits; and combined metals deposits. Occurrence data on over 40 other mineral commodities including sand and gravel, limestone, carbon dioxide, and geothermal fluid, were tabulated. Results are presented in tabular form and in map form. The maps show contours of mineral potential for each of the five commodity categories classified.

In a separate but closely related project conducted by TERRADATA, a panel of geoscientists with experience in the CDCA classified the lands of the CDCA for potential of the following: metals, saline minerals, uranium and industrial minerals. The panel utilized the data and information collected for the geostatistical classification plus data from other sources. A separate report on the panel classification was prepared, but is not included here. It is Classification of the California Desert for Geology - Energy - Mineral Resource Potential, Expert Panel Classification, TERRADATA, July 1979.

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* In October 1980 the CDCA became the California Desert District (CDD) with headquarters in Riverside, California.

DISCLAIMER

This report was prepared under Contract Number YA-512-CT9-66 for the U.S. Department of the Interior, Bureau of Land Management, California Desert Program, 3610 Central Avenue, Suite 402, Riverside, California 92506. While officials of the Bureau of Land Management provided guidance and assistance in conducting the study, the contents do not necessarily represent the policies of the Bureau.

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Special thanks go to co - author Mr. Jean Juilland of the Bureau of Land Management's Desert Plan Staff. He conceived this project. His assistance as Project Officer was invaluable. His guidance regarding data sources, analyses and BLM's needs was essential. His staff willingly provided support and assistance whenever asked.

All members of the panel of experts provided comments through their panel work. They are John P. Albers, U.S. Geological Survey; John T. Awald, Systems Exploration, Inc.; Kenneth C. Bullock, Brigham Young University; James F. Davis, California State Geologist; Frederic G. Files, U.S. Department of Energy; Cliffton H. Gray, Jr., California Division of Mines and Geology; Paul K. Morton, California Division of Mines and Geology; Gordon B. Oakeshott, Consulting Geologist; Charles F. Park, Jr., Stanford University; and Ward C. Smith, Stanford University.

The manuscript has been reviewed by Michael Garratt, BLM statistician, and by Roger Haskins, BLM geologist.

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I. INTRODUCTION AND SUMMARY

Section 601 of Public Law 94 - 579, the Federal Land Policy and Management Act of 1976, charges the Bureau of Land Management (BLM) with the preparation of a plan for the multiple - use management of the California Desert Conservation Area (CDCA). This area is approximately 105,000 square kilometers (km^2) in southeasten California. Of this area some 76 percent is National Public Land managed by several government agencies. Slightly less than half of the total CDCA (48 percent) is managed by the BLM. The boundaries of the CDCA are shown in Figure 1. Its resources were inventoried to generate a multiple - resource database which BLM utilized to develop recommended land uses. Geology, energy and mineral (G - E - M) resources together form one of several groups of resources which were inventoried.

Data on G - E - M resources available at the time (1977) were not satisfactory for making recommendations on the potential for G - E - M resources on lands managed by BLM. For this reason a multi - method, integrated, systematic program for the inventory, analysis and classification of the G - E - M resources in the CDCA was developed. A separate technical report on the G - E - M Resources Inventory, Analysis and Classification Program will be published. This report presents the results of the Geostatistical Classification which was one of several methods used and integrated in the overall G - E - M resources program.

This report is the result of a two - year effort (1977 - 1979) by TERRADATA of data gathering and analysis coordinated by the G - E - M Resources Team of the BLM's Desert Plan Staff. This classification takes into account the results of all previous work conducted or sponsored by the G - E - M Resources Team. Two approaches to classification were applied. The first involved a systematic compilation of all the G - E - M related studies performed on the CDCA followed by an objective statistical classification. The second was more subjective in nature and involved classification of lands by a panel of experts, all with experience in the CDCA, but with different areas of expertise. The panel had access to all information compiled in the statistical classification process. The final results of both approaches consist of maps of the CDCA showing classification of land according to G - E - M resources potential. The maps are accompanied by reports. The panel effort is summarized in a separate report entitled A Classification of the California Desert for Geology - Energy - Mineral Resource Potential: Expert Panel Classification. Members of the panel of experts provided comments on this report through their panel work. They are:

John P. Albers, U.S. Geological Survey;
John T. Awald, Systems Exploration, Inc.;
Kenneth C. Bullock, Brigham Young University;
James F. Davis, California Division of Mines and Geology (CDMG);
Frederic G. Files, U.S. Department of Energy;
Cliffton H. Gray, Jr., CDMG;
Paul K. Morton, CDMG;
Gordon B. Oakeshott, Consulting Geologist;
Charles F. Park Jr., Stanford University; and
Ward C. Smith, Stanford University.

There are two major approaches to the statistical classification of mineral potential, both of which should be applied (Figure 2). The first is to classify all lands with known occurrences of minerals as areas of high potential. The second is to seek statistical relationships between geologic features (i.e., geologic, geophysical, geochemical, lineament and other features) of areas and mineral potential; and, if a relationship exists, to classify land using that relationship.

This report is a summary of the results of the geostatistical classification. More detailed information is provided in four appendices:

- Appendix A: Geology - Energy - Mineral Resource Occurrences in the CDCA;
- Appendix B: Geological, Geophysical, Geochemical, Tonal Anomaly and Lineament Data for the CDCA;
- Appendix C: Geostatistical Analysis; and
- Appendix D: Definition of Statistical Terms.

In addition to this report, all other maps, other reports and the magnetic tapes containing all data compiled for this project, are listed in Table 8.

The reports and maps listed in Table 8 are not published, but are available for study either in the library of the Bureau of Land Management office in Sacramento, California or at the Bureau of Land Management California Desert District office in Riverside, California.

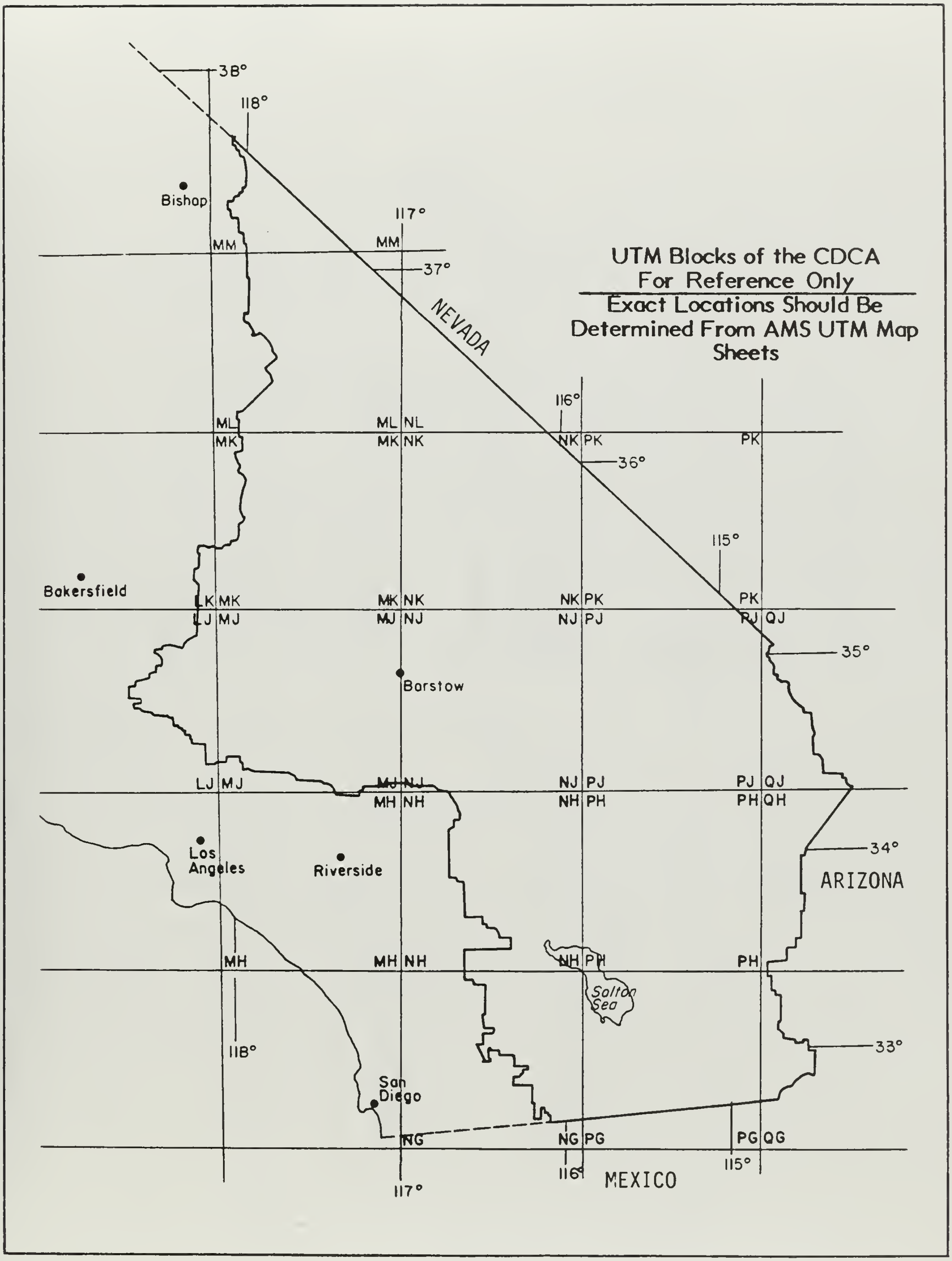

Figure 1
Map Of The CDCA Showing UTM Blocks

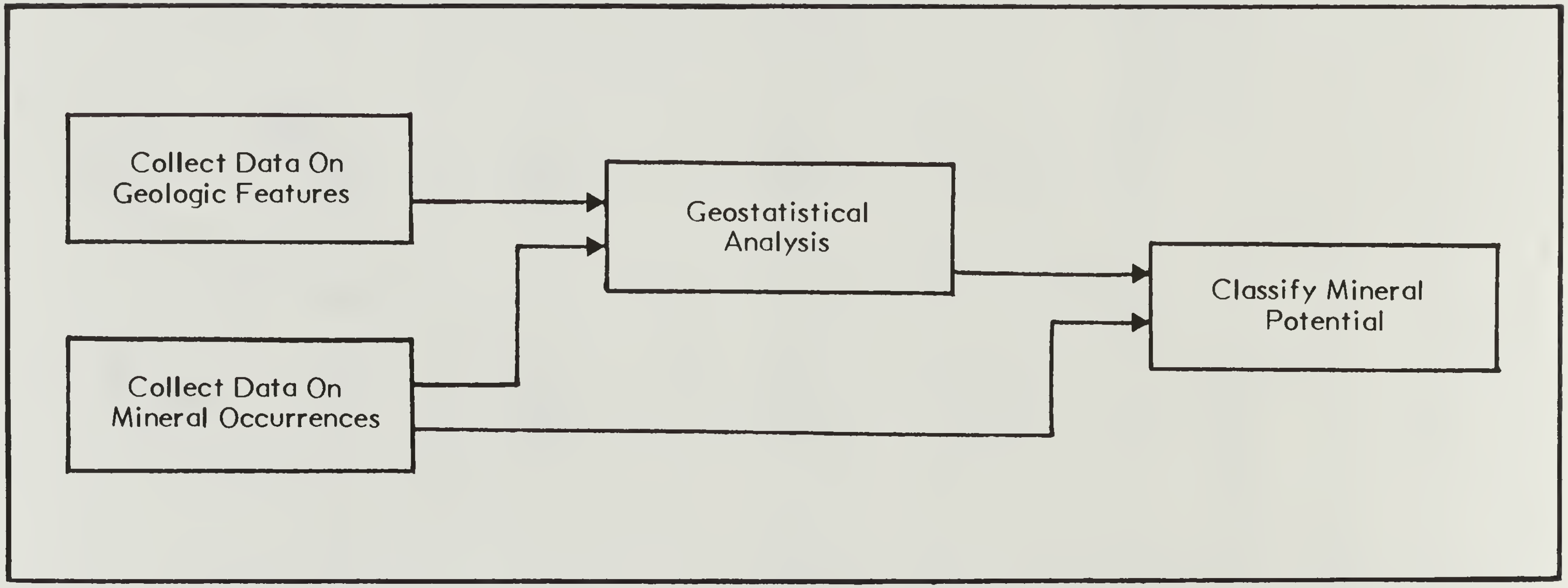

Figure 2

Flowchart Of Classification Procedure

2. DATA COMPILATION

The mineral potential of the CDCA was classified on an area-by-area basis. To accomplish this, the CDCA was divided into cells 4 kilometers by 4 kilometers (km) in size using the Universal Transverse Mercator (UTM) coordinate system. This system is discussed in detail in Appendix B.

Two types of data were compiled as follows:

1. All known and reported occurrences of G-E-M resources in the CDCA were compiled. A total of 3,146 occurrences of 47 G-E-M resources were identified. These occurrences are summarized in Table 1. Appendix A presents details on occurrence data.

2. Forty geologic variables represented on the Geologic Map of California; one geophysical variable (Bouguer gravity) and 20 lineament variables from each of four sources (LANDSAT imagery, Bouguer gravity contours and aerial and Skylab photography) were recorded on a cell-by-cell basis over the entire CDCA; i.e., data were encoded in numerical form for 26,810 cells (2 km by 2 km square). Three tonal anomaly variables, 30 geochemical variables, four gamma-ray spectrometric variables and aeromagnetic values were also recorded on a 4-km by 4-km cell basis. For reference purposes, each variable is assigned a number. These data are summarized in Tables 2, 3, 4, 5, 6 and 7. Appendix B presents details on these data. As discussed in Appendix B, the tonal anomaly, gamma-ray spectrometric, aeromagnetic, and geochemical data were available only for selected portions of the CDCA.

This database thus compiled provides the following:

- The data, when mapped or listed systematically, provide useful information for land-use planning decisions.

- The data form the basis for statistically classifying lands with respect to the potential for occurrence of certain mineral resources.

- The data can be used for expert panel classification.

A summary list of the maps provided by TERRADATA is given in Table 8.

Table 1

Mineral Occurrences In The CDCA[a]
By Commodity And Production Category

Commodity	Symbol	Production Category[b]					Total All Categories
		0	1	2	3	4	
Metals							
Antimony	Sb	3	5	8	0	0	16
Copper	Cu	86	146	80	12	0	324
Gold	Au	166	400	172	46	22	806
Iron	Fe	29	27	19	1	0	75
Lead	Pb	69	87	46	16	5	223
Manganese	Mn	26	49	21	3	3	102
Mercury	Hg	5	3	1	0	0	9
Nickel	Ni	1	2	0	0	0	3
Molybdenum	Mo	1	1	1	0	0	3
Rare earths	RE	5	7	0	0	1	13
Silver	Ag	5	47	22	2	4	80
Tin	Sn	1	1	0	0	0	2
Titanium	Ti	0	1	0	0	0	1
Thorium	Th	0	1	0	0	0	1
Tungsten	W	30	70	45	3	3	151
Uranium	U	115	15	14	0	0	144
Vanadium	Va	0	1	0	0	0	1
Non-Metals							
Asbestos	As	3	0	1	0	0	4
Barium	Ba	10	7	6	0	0	23
Clay	Cl	13	28	25	5	2	73
Dimension stone	Ds	7	9	18	0	0	34
Feldspar	Fd	8	4	4	0	0	16
Fluorspar	Fl	6	9	3	0	0	18
Gemstones	Gs	22	13	3	0	0	38
Limestone	Ls	84	47	24	4	3	162
Magnesite	Mg	1	9	4	0	0	14
Mica	Mi	3	3	6	0	0	12
Roofing granules	RG	0	1	9	0	0	10
Sand and gravel	SG	100	20	305	17	27	469
Silica	Si	10	1	10	1	1	23
Sulfur	S	1	2	2	0	0	5
Talc	Tc	24	20	11	12	7	74
Volcanic cinders	VC	29	18	18	0	0	65
Wollastonite	Ws	1	1	1	0	0	3
Miscellaneous	Ms	2	2	2	0	0	6
Salines							
Borates	B	35	2	15	2	2	56
Calcium chloride	CC	1	1	3	0	0	5
Gypsum	G	19	7	11	0	1	38
Magnesium salts	MC	1	0	0	0	0	1
Potassium salts	KS	1	1	5	0	0	7
Salt	NC	5	3	10	0	0	18
Sodium carbonate	SC	0	0	4	0	0	4
Sodium sulfate	SS	5	0	2	0	0	7
Strontium	Sr	3	0	4	0	0	7
Total All Commodities		935	1,071	935	124	81	3,146
Wells							
Oil and gas (all are dry holes)							188
Carbon dioxide							8
Geothermal							88
Total Wells							284

[a] Data on hot springs (HS) is included in the data base but has not been tabulated.

[b]
0 = Occurrence or claim
1 = Worked, but no production reported
2 = Small Producer (less than $50,000)
3 = Moderate Producer ($50,000 to $500,000)
4 = Major Producer (over $500,000)

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see p.~~38~~ for definition of dollar values
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Table 2

Geological And Geophysical Variables For The CDCA

Lithologic Units

Variable Number	Description	Areal Extent Within CDCA (km^2)	% Of CDCA Area
1.	Precambrian granitic rocks. - Precambrian anorthosite. - Undivided Precambrian granitic rocks.	701	0.67
2.	Precambrian metamorphic rocks. - Precambrian igneous and metamorphic rock complex. - Earlier Precambrian metamorphic rocks. - Later Precambrian sedimentary and metamorphic rocks. - Undivided Precambrian metamorphic rocks.	5,542	5.28
3.	Cambrian and late Precambrian sedimentary rocks. - Cambrian and Precambrian marine. - Cambrian marine.	1,963	1.87
4.	Ordovician through Mississippian marine sedimentary rocks. - Ordovician marine. - Pre-Silurian metasedimentary rocks. - Silurian marine. - Devonian marine. - Mississippian marine. - Paleozoic marine.	2,318	2.21
5.	Pennsylvanian through Permian marine sedimentary rocks. - Pennsylvanian marine. - Undivided carboniferous marine. - Permian marine.	489	0.47
6.	Pre-Cretaceous metasedimentary rocks and pre-Cretaceous metamorphic rocks.	1,298	1.24
7.	Paleozoic and Precambrian metavolcanic rocks. - Pre-Silurian metamorphic rocks. - Pre-Silurian metavolcanic rocks. - Devonian and pre-Devonian metavolcanic rocks. - Devonian metavolcanic rocks. - Carboniferous metavolcanic rocks. - Permian metavolcanic rocks. - Paleozoic metavolcanic rocks.	14	0.01

Table 2

Geological and Geophysical Variables For The CDCA Lithologic Units
(Continued)

8.	Triassic-Jurassic marine sediments. - Triassic marine. - Middle and/or Lower Jurassic marine. - Upper Jurassic marine. - Knoxville Formation.	28	0.03
9.	Pre-Cretaceous metavolcanic rocks (if age cannot be established other than pre-Cretaceous). - Pre-Cretaceous metavolcanic rocks. - Jura-Triassic metavolcanic rocks.	472	0.45
10.	Mesozoic basic intrusives. - Mesozoic ultrabasic intrusive rocks. - Mesozoic basic intrusive rocks.	277	0.26
11.	Mesozoic granitic intrusives and pre-Cenozoic granitic and metamorphic rocks.	14,431	13.76
12.	Eolian deposits.	3,271	3.12
13.	Tertiary sediments (marine and nonmarine).	2,860	2.73
14.	Tertiary igneous intrusives (hypabyssal).	515	0.49
15.	Tertiary volcanics. - Eocene volcanics. - Oligocene volcanics. - Miocene volcanics. - Pliocene volcanics.	5,142	4.90
16.	Quaternary sediments. - Plio-Pleistocene nonmarine. - Pleistocene nonmarine. - Pleistocene marine and marine terrace deposits. - Quaternary nonmarine terrace deposits. - Glacial deposits. - Salt deposits. - Basin deposits. - Fan deposits. - Stream channel deposits. - Alluvium.	61,815	58.93
17.	Quaternary volcanics. - Pleistocene volcanics. - Recent volcanics.	1,652	1.57
18.	Bodies of water and unmapped areas.	2,112	2.01
	TOTAL	104,900	100.0

Table 3

Geological And Geophysical Variables For The CDCA

Rock Contact Relationships

Variable Number	Description	Total Length In CDCA (Km)
19	Length of contact between Precambrian granitic rocks (1) and Precambrian metamorphic rocks (2).	481.0
20	Length of contact between Mesozoic granitic intrusives and pre-Cenozoic granitic and metamorphic rocks (11), and either Ordovician through Mississippian marine sedimentary rocks (4), or Pennsylvanian through Permian marine sedimentary rocks (5).	565.0
21	Length of contact between Mesozoic granitic intrusions and pre-Cenozoic granitic and metamorphic rocks (11) and Triassic-Jurassic marine sediments (8).	1.6
22	Length of contact between Tertiary igneous intrusives (14) and Precambrian granitic rocks (1).	0.8
23	Length of contact between Tertiary igneous intrusives (14) and Precambrian metamorphic rocks (2).	53.2
24	Length of contact between Tertiary igneous intrusives (14) and Cambrian and late Precambrian sedimentary rocks (3).	3.2
25	Length of contact between Tertiary igneous intrusives (14) and Ordovician through Mississippian marine sedimentary rocks (4).	5.2
26	Length of contact between Tertiary igneous intrusives (14) and Pennsylvanian through Permian marine sedimentary rocks (5).	9.6
27	Length of contact between Tertiary igneous intrusives (14) and pre-Cretaceous metasedimentary rocks and pre-Cretaceous metamorphic rocks (6).	7.2
28	Length of contact between Tertiary igneous intrusives (14) and Paleozoic and Precambrian metavolcanic rocks (7).	2.8
29	Length of contact between Tertiary igneous intrusives (14) and Triassic-Jurassic marine sediments (8).	2.8
30	Length of contact between Tertiary igneous intrusives (14) and pre-Cretaceous metavolcanic rocks (9).	2.8
31	Length of contact between Tertiary igneous intrusives (14) and Mesozoic basic intrusives (10).	4.8
32	Length of contact between Tertiary igneous intrusives (14) and Mesozoic granitic intrusives and pre-Cenozoic granitic and metamorphic rocks (11).	208.0
33	Length of contact between Tertiary igneous intrusives (14) and Tertiary sediments (13).	83.0

Table 4

Geological And Geophysical Variables And Number Of Subcells For the CDCA

Structural Relationships

Variable Number	Description	Total In CDCA
34.	Length of thrust faults (km).	518
35.	Number of thrust faults.	415
36.	Length of nonthrust faults (km).	14,907
37.	Number of nonthrust faults.	12,629
38.	Number of fault intersections.	1,889
39.	Curvature of thrust faults.	n/a
40.	Curvature of nonthrust faults.	n/a
41.	Gravity value measured at cell center.	n/a
42.	Number of subcells.	26,812

Table 5

Lineament Variables For The CDCA

Variable Number	Source	Variable Description
43	LANDSAT	Number of Intersections
44	LANDSAT	Length of lineaments which intersect
45	LANDSAT	Number of lineaments passing through the cell
46	LANDSAT	Total length of lineaments passing through the cell
47-54	LANDSAT	Number of lineaments passing through the cell for each of 8 azimuth classes(1)
55-62	LANDSAT	Cumulative length of lineaments passing through the cell for each of 8 azimuth classes(1)
Not Numbered	Gravity	Number of Intersections
	Gravity	Length of lineaments which intersect.
	Gravity	Number of lineaments passing through the cell
	Gravity	Total length of lineaments passing through the cell
	Gravity	Number of lineaments passing through the cell for each of 8 azimuth classes(1)
	Gravity	Cumulative length of lineaments passing through the cell for each of 8 azimuth classes(1)
Not Numbered	Aerial	Number of intersections
	Aerial	Length of lineaments passing through the cell
	Aerial	Number of lineaments passing through the cell
	Aerial	Total length of lineaments passing through the cell
	Aerial	Number of lineaments passing through the cell for each of 8 azimuth classes(1)
	Aerial	Cumulative length of lineaments passing through the cell for each of 8 azimuth classes(1)
Not Numbered	Skylab	Number of intersections
	Skylab	Length of lineaments passing through the cell
	Skylab	Number of lineaments passing through the cell
	Skylab	Total length of lineaments passing through the cell
	Skylab	Number of lineaments passing through the cell for each of 8 azimuth classes(1)
	Skylab	Cumulative length of lineaments passing through the cell for each of 8 azimuth classes(1)

(1) Azimuth Classes

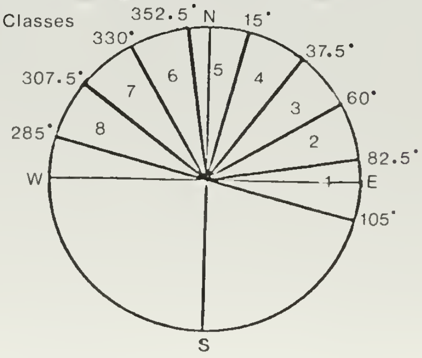


Table 6

Tonal Anomaly Variables For The CDCA

Variable Number	Variable Description
63	Total size of all anomalies partially or completely within a cell
64	The sum of sizes of that part of each anomaly contained within a cell
65	Number of anomalies present within a cell

Table 7

Geochemical Variables For The CDCA

Variable Number	Sieved Samples	Variable Number	Heavy Mineral Concentrate Samples
66	Magnesium	81	Magnesium
67	Titanium	82	Titanium
68	Mangenese	83	Manganese
69	Boron	84	Silver
70	Barium	85	Barium
71	Beryllium	86	Beryllium
72	Cobalt	87	Cobalt
73	Chromium	88	Chromium
74	Copper	89	Copper
75	Molybdenum	90	Molybdenum
76	Niobium	91	Lead
77	Lead	92	Tin
78	Vanadium	93	Zinc
79	Zinc	94	Potassium
80	Cerium	95	Cerium

Table 8

Maps And Reports Compiled In This Study

Maps

Map of Reported Mineral Occurrences in the CDCA (1:250,000 and 1:500,000)

Map Showing Wells (oil, gas, CO_2 and geothermal fluids) Drilled in the CDCA (1:250,000 and 1:500,000)

Maps of Reported Mineral Occurrences in the CDCA (1:1,000,000) for each of the following commodities:

- Gold
- Lead
- Silver
- Manganese
- Iron
- Tungsten
- Uranium
- Sand and Gravel Pits
- Saline Deposits

Maps of Reported Mineral Occurrences in the CDCA (1:250,000 and 1:500,000) for each of the following commodity categories:

- Metals
- Industrial Minerals
- Uranium
- Salines

Maps of Geochemical Sampling Locations in the CDCA (Four separate areas at 1:250,000 and 1:500,000)

Contour Maps of Geochemical Sampling Data in the CDCA (120 maps total) - Individual maps for four separate areas at 1:250,000 and 1:500,000 for each of the thirty elements:

Sieved Samples	Heavy Mineral Concentrate Samples
Magnesium	Magnesium
Titanium	Titanium
Boron	Silver
Barium	Barium
Beryllium	Beryllium
Cobalt	Cobalt
Chromium	Chromium
Copper	Copper
Molybdenum	Molybdenum
Niobium	Lead
Lead	Tin
Vanadium	Zinc
Zinc	Potassium
Cerium	Cerium

Table 8

(Continued)

Contour Maps of NURE Gamma-Ray Spectrometric Data in Goldfield, Death Valley, Trona, Kingman and Needles Quadrangles (1:250,000 and 1:500,000) for the following:

Bismuth (^{214}Bi)
Thallium (^{208}Tl)
Potassium (^{40}K)
Bismuth/Thallium ratio

Panel Classification Maps (1:250,000 and 1:500,000) for each of the following commodity categories:

Metals
Salines
Uranium
Nationally Important Industrial Minerals
Regionally Important Industrial Minerals
Sand and Gravel

Classification Maps of Lands in the CDCA (1:250,000 and 1:500,000) showing potential for each of the following commodities:

Gold
Iron
Manganese
Tungsten
Copper-Lead-Silver-Zinc combined
Combined metals

Reports And Data Tapes

"A Geostatistical Study for Geology-Energy-Mineral Resources in the California Desert," March 1978.

"Magnetic Tape Descriptions and Specifications" and corresponding magnetic tape, March 1978.

"A Geostatistical Study for Geology-Energy-Mineral Resources in the California Desert," December 1978.

"Magnetic Tape Descriptions and Specifications," and corresponding magnetic tape, December 1978.

"Classification of the California Desert for Geology-Energy-Mineral Resource Potential, Geostatistical Classification," July 1979.

"Magnetic Tape Description and Specifications," and corresponding magnetic tape, July 1979.

"Classification of the California Desert for Geology-Energy-Mineral Resource Potential, Expert Panel Classification," July 1979.

3. CLASSIFICATION TECHNIQUES

The potential for selected mineral resources in the CDCA is classified according to the probability of occurrence of the designated resource categories. The classifications are based upon (1) the location of the known mineral occurrences and (2) the results of geostatistical analysis. Each 4 - km by 4 - km cell has been classified.

Four statistical methods were considered for predicting potential of G - E - M resources. These were cluster, D - square similarity analysis, multiple linear regression analysis and discriminant function analysis (DFA). Previous research (Reference 138) has shown that DFA provides the most useful information for this particular study.

DFA results were presented for the following commodity categories:

- Combined Copper, Lead, Silver, Zinc
- Gold
- Iron
- Manganese
- Tungsten
- Combined Metals

3.1 INTRODUCTION TO DFA WITH EXAMPLE

This section of the report presents a summary review of DFA. Additional details are available in References 96 through 102 and Appendix C. Definitions of terms are in Appendix D.

DFA is a statistical procedure for assigning an individual entity (e.g., a cell) to a category (e.g., "occurrence" or "non - occurrence") based on its particular measurable attributes (e.g., geologic variables). The procedure takes place in the following steps:

1. Select categories for assignment.
   "Occurrence" and "non - occurrence"

2. Select, measure and digitize attributes.
   Geologic variables no. 1 - 62

3. Select Training Set.
   Known occurrence and non - occurrence cells

4. Calculate the discriminant function
   Use discriminant software

5. Use discriminant function to assign categories.
   Assign cells to "occurrence" or "non - occurrence"

6. Contour results.
   Use SURFACE II contouring software

These steps are explained on the next few pages.

Step 1: Select Categories for Assignment

In this study, the categories were "occurrence" or "non - occurrence" of G - E - M resources for each of the 6,850 4 km by 4 km cells in the CDCA.

Step 2: Select and Measure Attributes

The attributes were those related to mineralization. They are described in Tables 2, 3, 4 and 5. In a simplified example for explanation purposes only, assume there are four cells and six attributes (called variables) as follows:

Variable	Cell NG0000*	Cell NG0004	Cell NG0008**	Cell NG0012
1. Percent of cells containing Ordovician through Mississippian sedimentary rocks	75	30	20	91
2. Percent of cells containing Mesozoic granitic intrusives	25	70	80	9
3. Length of contact (km) between 1 and 2 above	4	2	3	1
4. Length of nonthrust faults (km) in cell	0	4	2	0
5. Bouguer Gravity value (milligals)	41	73	57	71
6. Total length (km) of lineaments passing through cell	36	36	0	83

* Occurrence cell
** Non - Occurrence cell

Once the variables are measured, they are digitized and entered into a computerized database.

Step 3: Select Training Set

The training set is selected as representative of the entire area or of major portions of it. It contains cells with known occurrences and cells where non - occurrence is assumed with some degree of certainty. In the simplified example, cell NG0000 is an "occurrence" cell and cell NG0008 is a "non - occurrence" cell. These are in the training set. The remaining two cells, NG0004 and NG0012, are the "target set."

Step 4: Calculate the Discriminant Function

The computer program DISCRIMINANT (Reference 96) develops a discriminant function using the training set. The function is in the form,

$$SCORE = aA_1 + bA_2 + cA_3 + \ldots, + nA_n$$

where the SCORE is called the discriminant score; a, b, c, . . ., n are coefficients calculated by the computer; and A_1, A_2, A_3, . . ., A_n are the measures of the attributes as described in step 2.

The function is developed so that the difference between the mean (average) of the discriminant scores for the occurrence cells and the mean of the discriminant scores for the non - occurrence cells is as large as possible.

In the simplified example, the coefficients and mean discriminant scores are shown below:

Variable	Coefficient
1	0.26
2	-0.29
3	0.15
4	0.11
5	-0.12
6	-0.06

Mean score for occurrence cells: 5.77
Mean score for non-occurrence cells: -24.17

Step 5: Use Discriminant Function to Assign Categories

Once the coefficients are developed, they are applied to each cell in the CDCA and a discriminant score is calculated for each cell. The score is then compared to the mean values of discriminant scores of cells in the training set. The cell is then assigned to the category whose mean score is closest to its score.

Results of applying this procedure to the simplified example are shown below:

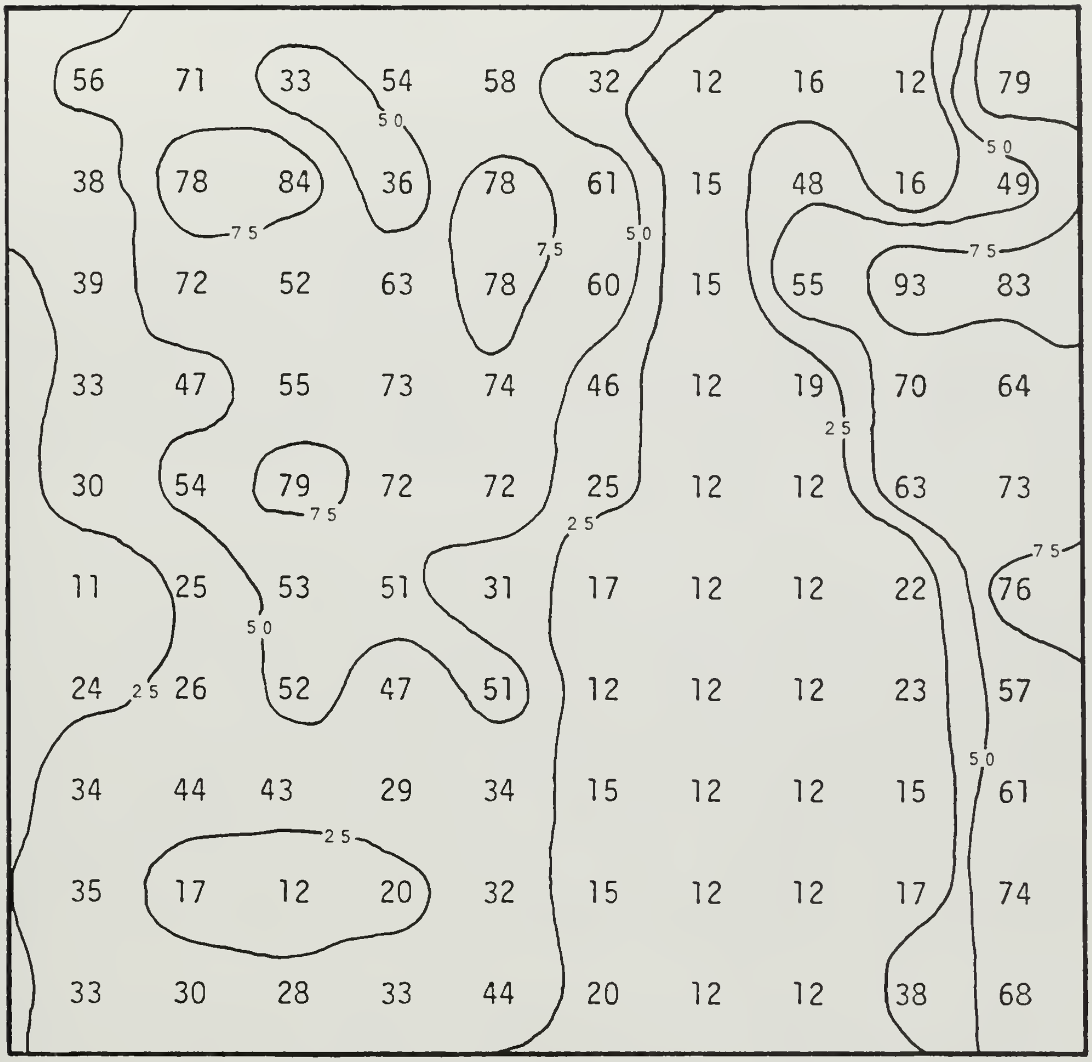
		Cell NG0004		**Cell Ng0012**	
Variable	Coefficient	Variable in Cell NG0004	Variable times Coefficient	Variable in Cell NG0012	Variable times Coefficient
1	0.26	30	7.8	91	23.66
2	-0.29	70	-20.3	9	-2.61
3	0.15	2	0.3	1	0.15
4	0.11	4	0.44	0	0
5	-0.12	47	-5.64	71	-8.52
6	-0.06	36	-2.16	83	-4.98
SCORE			-19.56		7.70
Assigment*		non - occurrence		occurrence	
Probability of Correct Classification		91%		97%	

* Mean score for occurrence cells: 5.77
Mean score for non - occurrence cells: -24.17

Since the scores for the target cells do not exactly match the group means for the training set, there is some likelihood that a target cell which is closer to the occurrence mean than the non - occurrence mean is, in fact, a non-occurrence cell. This is called a "misclassification." The DISCRIMINANT program calculates the probability of misclassification based on the closeness of a score to the group mean of the training set. The "probability of correct classification" is the complement of the probability of misclassification, i.e., they both sum to 1.

The discriminant function, once calculated, is also applied to the cells in the training set. In some cases, cells in the training set that are known "occurrence" cells may be classified by the function as a "non - occurrence" cell and vice versa. This is also called a misclassification. When the function correctly classifies a cell in the training set, it is called "correctly classified." The proportion of cells in the training set which are correctly classified by the discriminant function is one measure of the validity of the results of a particular DFA application.

Once all cells are classified, there is a group of tests which allow a judgment regarding the efficacy of the function and the usefulness of results. These tests are discussed in Section 3.2 below.



56	71	33	54	58	32	12	16	12	79
38	78	84	36	78	61	15	48	16	49
39	72	52	63	78	60	15	55	93	83
33	47	55	73	74	46	12	19	70	64
30	54	79	72	72	25	12	12	63	73
11	25	53	51	31	17	12	12	22	76
24	26	52	47	51	12	12	12	23	57
34	44	43	29	34	15	12	12	15	61
35	17	12	20	32	15	12	12	17	74
33	30	28	33	44	20	12	12	38	68

Figure 3

Example Of Contouring*

Each number is the probability (%) of correct Classification in the "occurrence" category for a 4 km x 4 km cell.

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* Contour interval is 25 percent.

Step 6: Contour Results

Once the discriminant function has been applied to each cell and each cell has been assigned to the "occurrence" or "non - occurrence" category, and once the probabilities of correct classification are assigned and the tests of results applied, then the results are ready for presentation. Figure 3 shows an example of contours plotted from a grid of probabilities of correct classification for each cell.

3.2 PRINCIPLES AND TESTS OF SIGNIFICANCE OF DFA

Discriminant Function Analysis (DFA) is a technique for assigning members of some set to a class. In this study, the set is the set of geographic cells (4 km x 4 km) in the CDCA, and the two classes used were: (1) mineral resource potential; and, (2) no mineral resource potential. The assignment is based on a relationship or correlation between a dependent variable (reported mineral occurrences) and a set of known independent variables (geologic, geophysical, geochemical, lineament, and other variables). This relationship, called a discriminant function, is measured using a computer for a portion of the CDCA called the "training set." The training set is merely a subset of the entire area that is representative of the geology and mineral environment of the region as a whole, or of a major portion of the region.

For the training set, cells with reported occurrences (designated "occurrence cells") are taken to indicate mineral resource potential. Cells with no reported occurrences (designated "non - occurrence cells") are taken to indicate no mineral resource potential. The discriminant function takes the values of the independent variables in each cell in the training set and calculates a score. If the discriminant function is valid, the scores of the known occurrence cells will be clustered, the scores of the non - occurrence cells will be clustered and the two clusters will not be close together. The mean score of each cluster, called the group mean, is calculated. The group 1 mean is the mean value of the scores of the occurrence cells. The group 2 mean is the corresponding value for the non - occurrence cells. There are three statistical methods to test the validity of the DFA appraoch. The first measure of the validity of the discriminant function is the statistical significance of the separation between the group means. This is measured using a test for significance called an F - test.

Once the discriminant function is calculated and its significance tested, it is applied to the independent variables of every cell in the CDCA, including those in the training set, to derive a score for each cell. The scores are compared to the group means. Each cell is then classified into the group which has the group mean closest to the cell's score.

The second measure of the validity of the discriminant function is the percentage of known occurrence cells in the training set that are correctly classified by the discriminant function into the occurrence category. The third measure of validity, and one might argue the acid test, is the percentage of known occurrence cells not in the training set, correctly classified in the mineral occurrence category.

Notice that the corresponding tests for non - occurrence cells are not used, i.e., the percentage of non - occurrence cells correctly classified in the non - occurrence category. The reason for this is the uncertainty that a cell with no reported occurrences has no mineral potential. Indeed, a non - occurrence cell may simply never have been explored. On the other hand there is reasonable certainty (not 100 percent) that a cell with a reported occurrence does have mineral potential.

The final result of DFA is the calculation of a probability for each cell. This probability is a measure of how close that cell's score is to the group mean of the group to which it has been assigned. A probability of 100 percent indicates that the score is identical to the group mean. A 90 percent probability indicates that the score is very close to the group mean, but not exactly the same. A 50 percent probability says the score is exactly between the two group means. The probability assigned to each cell is called the probability of correct classification. The distinction between the probability of correct classification and the probability of occurrence is that the former only measures how closely a score matches a calculated mean, while the latter also measures the correspondence between the group means and the real geologic environment. Therefore, a key assumption in the application of DFA is that the discriminant function does, in fact, correspond mathematically to the geologic factors affecting mineralization. Because of this, separate discriminant functions are required to assess the potential of minerals not normally found in similar geologic environments. Thus, in this study, separate analyses were performed for gold; iron; manganese; tungsten; and the combination of copper, lead, silver and zinc. The last group, referred to as the "hydrothermal" case, can be combined because the minerals occur in similar geologic environments.

4. RESULTS OF DISCRIMINANT FUNCTION ANALYSIS (DFA)

DFA was applied to six commodity categories. For visual presentation, maps showing the results of the DFA predictions for the six commodity categories were prepared at 1:250,000 and 1:500,000 scales. Maps at approximately 1:1,000,000 scale are contained in the pocket at the back of this report. Of five commodities listed below, maps for tungsten and manganese are not included in this report. In addition, a magnetic tape of all results was prepared. The maps show quartiles of probability of correct classification in the occurrence category (i.e., 0 - 25 percent, 25 - 50 percent, 50 - 75 percent; 75 - 100 percent probability of being the "occurrence" category). The six commodity categories are:

- Gold
- Combined Copper, Lead, Silver and Zinc (hydrothermal)
- Tungsten
- Iron
- Manganese
- Combined Metals

The combined metals map is derived from the other five by assigning each 4 - km by 4 - km cell the highest probability of correct classification of any of the other five cases and contouring the results.

It can be argued that genetically the gold data could be combined with the silver and perhaps with the copper, lead and zinc, to give a more statistically significant data set. However, because of uncertainty as to the quality of the source of the gold data set (numerous unsubstantiated gold claims have been reported) it was decided to keep the gold set separate rather than to risk a negative effect upon the other data sets. Only in the combined metals category was the gold data set mixed with the other data.

4.1 SIGNIFICANCE OF RESULTS

Except for the tonal anomaly and geochemical sampling data, all independent variables used in DFA are available for the entire CDCA. Thus, DFA was applied to the entire area without using the tonal anomaly and geochemical sampling variables. The significance of the results of these DFA applications are discussed in this section.

In addition, as a special case, DFA was applied only to the areas where tonal anomaly data are available and geochemical samples were collected. The geochemical and tonal anomaly variables do not improve the significance of the DFA results as discussed in Appendix C and, thus, were not used for the final DFA classifications.

Several methods are available to test the statistical significance of the results. These are discussed in Section 3.2 above. As shown in Table 9, all five commodity cases are within acceptable limits for these tests, though the results for iron and maganese are less significant than the others. The results for combined metals were not tested since they represent a combination of five different DFA cases.

TABLE 9

DFA Results - Tests Of Statistical Significance

	F-Test of Separation Between Group Means[a]		Percent of Occurrence Cells Correctly Classified[b]		
Case	F_0	$F_{.01}$	Training Set	Outside Training Set	Entire Area[d]
Hydrothermal*	11.25	1.94	61.3	57.5	59.4
Gold[c]	12.03	2.00	63.2	54.9	59.1
Tungsten	4.17	1.91	63.0	58.2	60.6
Iron	2.66	1.94	66.7	37.1	52.1
Manganese	3.57	2.08	64.1	42.1	53.2

(a) When F_0 exceeds $F_{.01}$, the separation is significant. All five cases are significant.

(b) In general, results less than 50% are considered questionable.

(c) Not including placer deposits.

(d) This column provided for information only. It is not a statistical test.

* "Hydrothermal" and "combined copper, lead, silver, zinc" are used interchangably in this report.

Perhaps the best measure of the effectiveness of DFA (not a test of statistical significance) is the ratio of percent of known occurrences correctly classified by DFA to the percent of area of the CDCA predicted to have high potential. The reason this comparison is important is that a function which assigns high potential to all cells of the CDCA will correctly classify all known occurrence cells, but will, at the same time, misclassify non - occurrence cells. There is no discrimination. It is necessary to have a selective function, i.e., one that assigns mineral potential to a reasonable number of cells and, at the same time, maintains the integrity of known high potential cells (occurrence cells) by assigning a high proportion of them to the occurrence category. In other words, the desirable situation is to have a high percentage of occurrence cells correctly classified, but only a moderate percentage of the CDCA predicted to have high potential. In this desirable situation, it is possible to make statements such as "DFA has correctly classified over 60 percent of the known occurrences while assigning high potential to less than 20 percent of the area." If DFA showed no discriminating power, one would expect that 60 percent of the CDCA would have to be classified as having mineral potential in order to classify correctly 60 percent of the known occurrences. Thus, the discriminating power can be measured by calculating the ratio of percent of occurrence cells correctly classified to percent of area classified in the high potential category. This number is referred to as the "high potential" ratio. The larger this number, the better is the discriminatory power of DFA. Table 10 summarizes this measure for each of the five commodity cases.

For comparison, a similar number was computed (last column of Table 10) to measure the ratio of the percent of occurrence cells in low potential cells to percent of area assigned low potential. The lower this number, the better is the discriminatory power of DFA. Comparison of the last two columns in Table 10 reveals a significant discriminating ability. If there were no discriminating ability, all the entries in columns 3 and 4 would be expected to have values very close to one. Instead, the "high potential" ratios are all 2.5 or higher and the "low potential" ratios are near 0.6 or lower.

Another measure of the effectiveness of DFA is to see how many known occurrences are in cells predicted to have low potential. (This test is performed on all occurrences of a given commodity. The previous test was for occurrence cells only. The distinction arises from the fact that one occurrence cell could contain several occurrences.) This test was performed for two definitions of low potential.

First, any cell with a probability of correct classification in the occurrence category of 25 percent or less was considered to have low potential. The results are shown in Table 11. In each case, although a large percentage of the CDCA is classified as low potential (up to 60 percent) a very low percentage of known deposits are in those areas. Furthermore, by far the predominant number of deposits in those areas never reported any production (production categories 0 or 1 as discussed in Appendix A).

TABLE 10

DFA Results
Occurrence Cells Correctly Classified
Versus Areal Extent Of Occurrence Cells

	(1)			(2)	(3)	(4)
Case	Percent of Occurrence Cells Correctly Classified			Percent of CDCA Classified With Mineral Potential[(a)]	Ratio[(b)] High Potential	Ratio[(c)] Low Potential
	Training Set	Outside Training Set	Entire CDCA			
Copper, Lead, Silver, Zinc*	61.3	57.5	59.4	24.1	2.5	.53
Gold[(d)]	63.2	54.9	59.1	23.7	2.5	.54
Tungsten	63.0	58.2	60.6	22.6	3.0	.49
Iron	66.7	37.1	52.1	20.1	2.6	.60
Manganese	64.1	42.1	53.2	19.6	2.7	.58

(a) - Probability of correct classification in the occurrence category greater than 50 percent.

(b) - This is the ratio of column 3 (percent of occurrence cells correctly classified in the entire CDCA) to column 4 (percent of area classified in the higher mineral potential category).

(c) - This is the ratio of percent of occurrence cells classified in the non-occurrence category (misclassifications) to percent of area classified in the lower mineral potential category. It is 100 minus the entry in column 3 divided by 100 minus the entry in column 4.

(d) - Not including placer deposits.

* "Hydrothermal" and "combined copper, lead, silver, zinc" are used interchangably in this report.

TABLE II

DFA Results
Known Deposits In Low Probability (25 Percent)(b) Cells

Case	Total # Of Occurrences	Number of Known Deposits In Low Probability Cells							Percent Of CDCA Classified Low Probability(b)
		Production Category(a)					Total	Percentage	
		0	1	2	3	4			
Copper, lead, silver, zinc *	627	13	19	5	0	0	37	6	32.6
Gold(c)	757	21	34	10	5	3	73	10	47.5
Tungsten	144	0	8	4	1	1	14	10	59.9
Iron	75	8	4	3	1	0	16	21	58.7
Manganese	102	2	6	3	0	0	11	11	44.6

(a) - Production Categories

0 = Occurrence
1 = Workings, but no producion
2 = Production under $50,000
3 = Production between $50,000 and $500,000
4 = Production over $500,000

(b) - 25 percent or less probability of correct classification in the occurrence category

(c) - Not including placer deposits

* "Hydrothermal" and "combined copper, lead, silver, zinc" are used interchangably in this report.

TABLE 12

DFA Results
Known Deposits In Low Probability (50 Percent)[b] Cells

Case	Total # Of Occurrences	Number of Known Deposits In Low Probability Cells							Percent Of CDCA Classified Low Probability[b]
		Production Category[a]					Total	Percentage	
		0	1	2	3	4			
Copper, lead, silver, zinc*	627	64	114	54	7	2	241	38	65.9
Gold[c]	757	80	113	41	15	7	256	34	76.3
Tungsten	144	11	32	21	1	2	67	47	77.4
Iron	75	13	15	8	1	0	37	49	79.9
Manganese	102	15	16	11	1	0	43	42	80.4

(a) - Production Categories

0 = Occurrence
1 = Workings, but no producion
2 = Production under $50,000
3 = Production between $50,000 and.$500,000
4 = Production over $500,000

(b) - 50 percent or less probability of correct classification in the occurrence category

(c) - Not including placer deposits

* "Hydrothermal" and "combined copper, lead, silver, zinc" are used interchangably in this report.

TABLE 13

Variables Selected By DFA

Variable Set	Variable Components		Variables Selected For Discrimination				
	Number	Description	Hydrothermal(1)	Gold	Tungsten	Iron	Manganese
1.	1.	Precambrian granitic rocks.	X	X	X		X
2.	2. 6. 7. 9.	Cambrian metamorphic rocks. Pre-Cretaceous metasedimentary rocks and pre-Cretaceous metamorphic rocks. Paleozoic and Precambrian metavolcanic rocks. Pre-Cretaceous metavolcanic rocks (if age cannot be established other than pre-Cretaceous).	X	X	X	X	
3.	3. 4. 5. 8.	Cambrian and late Precambrian sedimentary rocks. Ordovician through Mississippian marine sedimentary rocks. Pennsylvanian through Permian marine sedimentary rocks. Triassic-Jurassic marine sediments.	X				
4.	10.	Mesozoic basic intrusives.	X	X	X	X	X
5.	11. 14.	Mesozoic granitic intrusives and pre-Cenozoic granitic and metamorphic rocks. Tertiary igneous intrusives (hypabyssal).		X	X	X	
6.	13.	Tertiary sediments (marine and non-marine).		X		X	
7.	12. 16.	Eolian deposits. Quaternary sediments.	X	X		X	
8.	15. 17.	Tertiary volcanics. Quaternary volcanics.	X	X			X
9.	19.	Length of contact between Precambrian granitic rocks (1) and Precambrian metamorphic rocks (2).	X	X		X	X
10.	20. 21.	Length of contact between Mesozoic granitic intrusives and pre-Cenozoic granitic and metamorphic rocks (11), and either Ordovician through Mississippian marine sedimentary rocks (4), or Pennsylvanian through Permian marine sedimentary rocks (5). Length of contact between Mesozoic granitic intrusions and pre-Cenozoic granitic and metamorphic rocks (11) and Triassic-Jurassic marine sediments (8).	X			X	
11.	22. 23. 24. 25. 26. 27. 28. 29. 30. 31. 32. 33.	Length of contact between Tertiary igneous intrusives (14) and Precambrian granitic rocks (1). Length of contact between Tertiary igneous intrusives (14) and Precambrian metamorphic rocks (2). Length of contact between Tertiary igneous intrusives (14) and Cambrian and late Precambrian sedimentary rocks (3). Length of contact between Tertiary igneous intrusives (14) and Ordovician through Mississippian marine sedimentary rocks (4). Length of contact between Tertiary igneous intrusives (14) and Pennsylvanian through permian marine sedimentary rocks (5). Length of contact between Tertiary igneous intrusives (14) and pre-Cretaceous metasedimentary rocks and pre-Cretaceous metamorphic rocks (6). Length of contact between Tertiary igneous intrusives (14) and Paleozoic and precambrian metavolcanic rocks (7). Length of contact between Tertiary igneous intrusives (14) and Triassic-Jurassic marine sediments (8). Length of contact between Tertiary igneous intrusives (14) and pre-Cretaceous metavolcanic rocks. Length of contact between Tertiary igneous intrusives (14) and Mesozoic basic Intrusives (10). Length of contact between Tertiary igneous Intrusives (14) and Mesozoic granitic intrusives and pre-Cenozoic granitic and metamorphic rocks (11). Length of contact between Tertiary Igneous Intrusives (14) and Tertiary sediments (13).					
12.	34. 36.	Length of thrust fauls. Length of non-thrust faults.					
13.	38.	Number of fault intersections.				X	X
14.	41.	Gravity value measured at cell center.	X		X		X
15.	43.	Weighted number of LANDSAT lineaments which intersect in cell.			X		X
16.	46.	Sum of total length of LANDSAT lineaments passing through the cell.					X
17.	55.	Cumulative length of LANDSAT lineaments passing through the cell for each of 8 azimuth classes within an origin of 15°.			X		
18.	56.		X		X		
19.	57.				X		
20.	58.					X	
21.	59.				X	X	X
22.	60.						X
23.	61.			X			
24.	62.			X			

(1) Copper, lead, silver, zinc combined

Second, any cell with a probability of 50 percent or less was defined to have low potential. Those results are shown in Table 12. Once again, the observation holds. Despite the fact that nearly 80 percent of the area is classified as having low potential, less than 50 percent of the known deposits occur in those low potential areas, and of these, approximately 75 percent never reported any production. This test, too, is strong support for the discriminating ability of DFA.

In applying DFA, some variables were combined into variable sets. The variable set number is shown in the left column of Table 13. The gravity, aerial and Skylab variables in Table 5 were not used for DFA because they did not contribute to the discriminating power (see Appendix B). The procedure used by DFA selects the variables which provide the most discrimination between occurrence cells and non-occurrence cells. Table 13 shows those variable sets which provide the most discrimination for each of the commodity categories.

4.2 LIMITATION OF RESULTS

While the DFA results are useful for a "first cut" classification of mineral potential, there are sources of uncertainty. Some cautions for the use of the results are discussed below.

The classification was done as part of the development of a land use plan, not for mineral exploration purposes.

The fact that a particular cell in the training set contains no reported occurrences does not establish that there are absolutely no occurrences in it. Indeed, occurrences may be present which are unknown, or there may be occurrences which are known but not reported. Nevertheless, the lack of reported occurrences defines this particular cell as a "non-occurrence" cell in the training set. In fact, any cell that was either initially defined (in the training set) as a "non-occurrence" cell, or was subsequently classified by DFA as a "non-occurrence" cell, has some likelihood of containing one or more occurrences, especially considering the widespread occurrences of minerals in trace quantities in most rocks and sediments. Similarly, there is uncertainty concerning a cell which is initially defined or subsequently classified as an "occurrence" cell. Some of the reported occurrences may not be of economic importance in any sense and may have yielded little more than trace amounts. In addition, some reports of the presence of minerals may be in error.

The probability estimates of correct classification pertain to each 4-km by 4-km cell as a whole and not to a point or points within the cell. Comparison with the geologic map may suggest that only part of the cell has any actual potential for occurrence. Thus, for appraising a particular cell, the DFA results must be analyzed in the light of the geology in that cell.

The main source of geologic data is the 1:250,000 scale Geologic Map of California. This map, published in 1° by 2° quadrangles, is a compilation of other geologic maps prepared at different times, at different scales and by different persons with different objectives, interests and perceptions. More detailed geologic data might improve the reliability of the DFA results. Examples of such data are the presence of gossans; other evidence of alteration associated with ore deposits; and the presence of carbonates, especially where they have been invaded by granitic intrusives. However, there is only scant direct information concerning lithologic details of sedimentary sequences on the 1:250,000 scale maps.

In using the results of the geostatistical classification process, one should be aware of the following potential limitations:

1. The method rests on the assumption that the geologic, geophysical and lineament variables are related to mineralization, and that the relationships can be modeled statistically.
2. There is a subtle but important distinction between probability of occurrence and probability of correct classification in the occurrence category. (This is discussed in Appendix C).
3. There is uncertainty regarding the validity of the information on G-E-M occurrences since it may involve faulty reports.
4. There is the dilemma of assigning a cell with no reported occurrences to the "non - occurrence" category if that cell is in the training set.
5. The probability assignments actually apply to 4 - km by 4 - km cells as a whole and not to any specific point within the cell.
6. There are limitations in the sources of data upon which the geologic, geochemical, geophysical and lineament data are based.

5. USE OF RESULTS

The results of this study were used as follows:

A. In the early stages of the inventory program, the geostatistical study provided an initial feel for the potential of the CDCA for G - E - M resources. In addition the initial geostatistical study provided one of several means for evaluating where within the CDCA additional data were needed;

B. After additional data were gathered, a new geostatistical study was performed using the additional data. That study provided improved classification maps which geologists of the G - E - M Resources Team integrated with results from other studies to generate maps showing G - E - M resources potential for the CDCA;

C. The results of the geostatistical study were also integrated with results from other studies to prepare recommendations from the G - E - M Resources Team to the BLM Management for the CDCA multiple - use plan;

D. Finally, the study results, together with other G - E - M resources data and with other natural resources data, were used by BLM Management in reaching final decisions for the multiple - use management plan.

6. RECOMMENDATIONS

As indicated above, the results of this geostatistical study were used by BLM in developing recommendations for the multiple - resources land use plan for the CDCA. In addition to providing recommendations on the management of an important area, this type of study could serve as a prototype for similar efforts in other areas. The following recommendations are oriented toward both purposes: as a part of developing land use plans and as a prototype.

6.1 USEFULNESS OF APPROACH

The basic approach involved three phases: data gathering, digitizing and computerizing, and analysis. In the data gathering phase, every publicly available data source was consulted. Such an exhaustive search is essential. Once collected the data were digitized and entered into a computerized database. The large amount of data and data applications make use of computer facilities essential. In the analysis phase both statistical (objective) and expert panel (subjective) approaches were used. While both these methods may be subject to criticism, they are most effective in terms of making use of existing data, concepts and experience and, therefore, most efficient when considering cost and time per unit area.

The intent of the geostatistical analysis of G - E - M resources was to provide the G - E - M Resources Team with information for their classification of lands for G - E - M resources potential and their recommendations for a multiple - use plan for the CDCA. It is therefore principally a planning tool and not a guide for mineral exploration.

6.2 IMPROVEMENT OF DATABASE

The database used for the CDCA geostatistical study (this report and appendices) contains geologic, gravity and lineament data of high quality. Some modifications could be made, but unless the level of detail is considerably increased, the changes would represent only fine tuning of existing results. Such detailed and costly modifications might be appropriate for very small geographic areas, but not for multiple - use plans the scope of the CDCA study.

A much greater improvement in the results would be obtained by improving the reported occurrence file. The file lacks accurate production information (see Appendix A). Another problem is that claims were assumed to represent an occurrence of the commodity stated in the claim, though many claims probably contained inaccurate information. The reported occurrence database is the single most important element in the classification process, and any improvement would be beneficial. The field verification studies conducted by the G - E - M Resources Team before the geostatistical study was done, proved very useful for validating and upgrading some occurrence data.

6.3 EXPANSION OF INDEPENDENT VARIABLES

Expansion of the independent variables would also improve the results. The experiments with geochemical data, for instance, were encouraging, but not conclusive. The geochemical data are simply too limited in coverage and too sparse where available. Additional geochemical data collected over more of the CDCA using a finer sampling grid would probably improve the classifications. Other information that might improve the classification includes complete and consistant aeromagnetic data and hydrothermal alteration data.

6.4 TREATMENT OF ALLUVIAL AREAS

The largest void in the data is caused by the fact that approximately 60 percent of the CDCA is covered by alluvium. These areas are usually classified with low potential for metals. In general, any geologic evaluation technique would result in similar classification. Key questions are how deep is the cover? And what is underneath? Sub - surface maps showing the extent of alluvial fill and type of bedrock can be prepared which might assist in overcoming this problem. However, this kind of mapping was beyond the scope of the present study.

Appendices

- APPENDIX A -

GEOLOGY - ENERGY - MINERAL RESOURCE OCCURRENCES

I. INVENTORY OF DEPOSITS AND WELLS

This appendix presents details about the collection, encoding and analysis of reported occurrences of G - E - M resources in the CDCA. A complete compilation of known resource occurrences in the CDCA serves four purposes:

1. Information about the nature, extent and location of known G - E - M occurrences is required for land use planning.
2. Since it is likely that unknown G - E - M deposits are near existing deposits, the location of known occurrences is a possible indicator of the existence of as yet unidentified deposits.
3. By using geostatistical analysis, relationships between known resource locations and the local geologic environment may be found that would indicate potential resource locations with similar enviornments.
4. Information on occurrences is required for the expert panel classification.

Since information regarding deposits is considered proprietary by most owners, compilation of an accurate inventory is difficult. Some operators and owners will not reveal information about deposits unless required to do so by government regulations or by potential investors. Information which is reported publicly may be distorted, depending on the motivations of the operator or owner. For these reasons, any compilation of resources data must be considered partially incomplete and inaccurate.

The best publicly maintained source of information is the annual questionnaire submitted to the U.S. Bureau of Mines (USBM) by individual producers. Since these questionnaires are considered proprietary by USBM, they were not available for this study. A polling of individual producers was beyond the scope of this project. Except for the USBM questionnaire and information from individual producers, all other sources of information identified were utilized for this project. These sources are listed in the references.

Occurrences of 47 resource types have been reported in the CDCA as summarized in Table I of the main report. Of the total of 3,430 occurrences, 284 are wells drilled in search of oil, gas, carbon dioxide or geothermal fluids. Occurrences were assigned dollar values according to "Rules for Classification of Production Codes" (below). A complete computer printout and magnetic tape of all reported occurrences were developed as part of a previous study (Reference 94).

2. COMPILATION OF MINERAL OCCURRENCE INFORMATION

Information on each occurrence was gathered and encoded for entry into a computerized data base. Information for each occurrence includes the following, if available:

- Location (UTM coordinates, county, section, township, range)
- Commodity
- Reference
- Production Category
- Name of deposit
- Production and geologic information

Location

The procedure for obtaining the location of occurrences in the CDCA is as follows:

1. Start with the USGS 1:250,000 topographic sheets.
2. Plot the location of mines described in the CDMG County Reports (References 1 through 7).
3. Add the locations (not identified in 2) of uranium claims described in Department of Energy's preliminary reconnaissance reports (PRRs) (Reference 8).
4. Add the locations (not identified in 2 and 3) of mines described in the Southern Pacific Railroad's report, "Mineral Resources of Southern California" (Reference 13).
5. Add the locations (not identified in 2, 3 and 4) of mines presented on the
    a. CDMG Economic Mineral Maps (References 9, 10 and 11).
    b. USGS Mineral Occurrence Map (Reference 12).
6. Add the locations (not identified in 2, 3, 4, and 5) of mines described in the USGS's Planning Unit reports (References 14 through 19).
7. Add the locations (not identified in 2, 3, 4, 5 and 6) of mines identified by the U.S. Bureau of Mines' Mineral Industry Location System (MILS) (Reference 20).
8. Add the locations (not identified in 2 through 7) of limestone or dolomite deposits identified in The Mineral Economics of Carbonate Rocks, Limestone, Dolomite Resources of California (Reference 136).
9. Add the locations (not identified in 2 through 8) of industrial mineral occurrences identified by BLM (Reference 137).

Some confusion exists in reporting locations of occurrences because of inaccuracies in location, errors in reporting, or errors in one or more references. Occurrence data were carefully edited to eliminate "double counting" or combining separate occurrences. However, since field verification was not possible, there are unavoidable errors in the location information. These are believed to be relatively few and of minor significance.

Commodities

Each location is associated with one or more commodities. Commodities are listed in Table I of the main report. Locations where more than one commodity is reported are identified with the primary commodity produced. In cases where more than one commodity has been produced in significant quantity, each commodity is reported as a separate occurrence.

Occurrences are identified using the following format:

XX AA YYY

where XX is the county code (see Table A-1), AA is the commodity symbol (see Table I) and YYY is the sequence number for that commodity in that county. YYY begins with 001 and is increased occurrence by occurrence within each county. YYY is an identifier only and does not represent any other information. For example,

29 Au 105

is gold (Au) occurrence number 105 in Kern County (29).

References

The reference from which the information was obtained is listed for each occurrence, keyed to the references contained at the end of this report.

Production Category

For each occurrence, a production category 0 through 4 was assigned as defined below and shown in Table I. Because complete production data are available for very few mines, the following rules were used in classifying each occurrence.

TABLE A-1

County Codes

County	Code
Imperial	025
Inyo	027
Kern	029
Los Angeles	037
Mono	051
Riverside	065
San Bernardino	071
San Diego	073

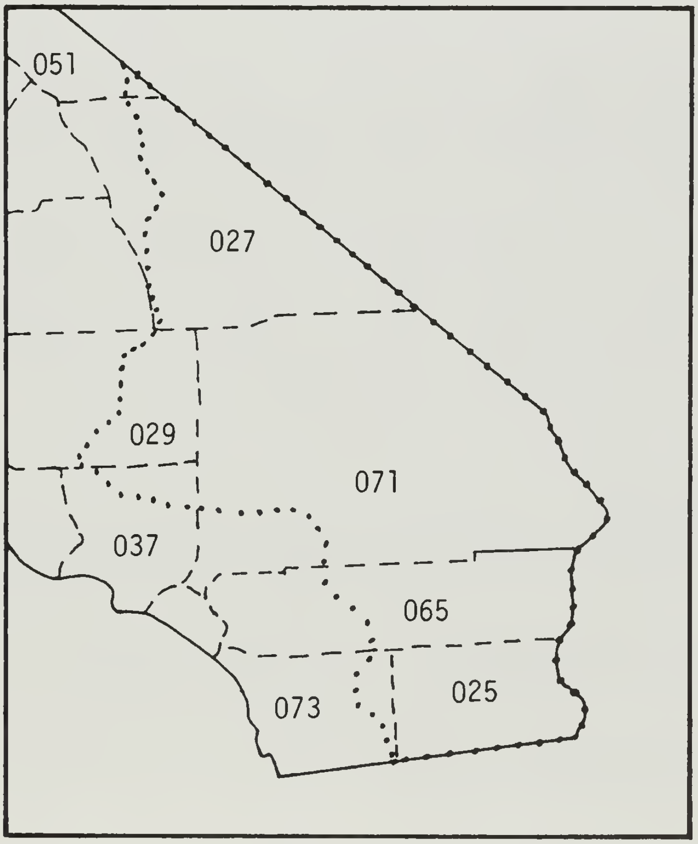

FIGURE A-1: Map Of CDCA Showing County Codes

Rules for Classification of Production Codes

1. All available production data are converted to dollars using the following conversions (1973 market prices are shown for comparison):

Commodity	Units	Conversion Price	1973 Market Price
Copper*	per pound	$.15	$.60
Gold*	per ounce	$25.52	$97.81
Lead*	per pound	$.06	$.16
Zinc*	per pound	$.07	$.21
Silver*	per ounce	$.61	$2.56
Iron#	per ton ore, unprocessed	$2.64	$12.11
Manganese#	per long ton ore (35% Mn or more)	$22.24	$36.00[+]
Tungsten#	per unit of WO_3	$14.32	$43.04
Talc#	per ton, crude	$6.50	$7.33

*New York Metal Market prices. Conversion price is average price over the years 1901 - 1950.
#These prices were obtained from the Bureau of Mines <u>Minerals Yearbook</u>. Conversion price is average price over the years 1901 - 1950.
+Estimated.

In some cases in the literature, production history was reported in terms of <u>quantity</u> (e.g., ounces of gold or tons of iron ore). In other cases, production was reported in terms of <u>value</u> (e.g., $498,000 of gold). For statistical purposes, it was necessary to show production history on a consistent basis. Since value figures did not always show year or years when mining occurred, it was not possible to convert to a specific adjusted dollar value. Thus, quantities were converted to value using average prices. As a result, production values are on a consistent, but not current, price basis. The purpose was to rank occurrences into one of five classes according to economic value. This method of ranking, while not reflecting current market values, is accurate in classifying occurrences. The specific category divisions ($50,000 and $500,000) were chosen to yield reasonable statistical distributions in each category, not because of their absolute value. Values were averaged over the 50 - year period, 1901 to 1950.

2. Sand and gravel pits are assigned production categories on the basis of production capacity as follows:
   Production category 2 if production capacity is less than 100 tons per hour.
   Production category 3 if production capacity is 100 to 1,000 tons per hour.
   Production category 4 if production capacity is over 1,000 tons per hour.

3. If production data are given for selected years only, they are treated as the only years of operation and converted to dollars as in 1 above.

4. If tonnages or grades of ore are not given, but production is indicated, the mine is assigned to Production Category 2.

5. If no production is indicated, but an adit, shaft, pit or other sign or workings exists, the mine is assigned to Production Category 1.

6. Otherwise, the mine is assigned to Production Category 0. This mainly includes (a) mines identified by MILS with no indication of production and (b) mines located in

the USGS "Reported Occurrence of Selected Minerals" but which are not referred to in some other source.

7. "Preliminary Reconnaissance Reports of Uranium Occurrences" are classified as follows:

Production Category 0 = Locations where radiation is more than three times background
Production Category 1 = Workings
Production Category 2 = Department of Energy "labeled reserves"

MILS Reference Number

The Mineral Industry Location System (MILS) is maintained as a computerized data base by the USBM. Each reported occurrence in MILS is coded in the form:

AA BBB CCCCC

where:

AA is the state code (California's code is 06).
BBB is the county code. County codes in the CDCA are shown in Table A-1.
CCCCC is the MILS reference number.

Since the state code is the same for all entries and the county code (less its beginning zero) is part of the commodity identification, only CCCCC is included as a separate entry in the production database.

Other Information

Other information includes the name of the mine or claim and specific production and geologic formation.

3. OIL, GAS, CO_2 AND GEOTHERMAL WELLS

OIL AND GAS WELLS

There are no known oil or gas fields in the CDCA. In general, the oil and gas potential is very low. However, there have been sporadic attempts at oil and gas exploration since 1920. All of these attempts resulted in dry holes, although some encountered traces or "shows" of oil and gas. While most of the wells have been drilled by operators not regularly associated with the oil industry, a few of the wells were drilled by major oil companies. These were drilled to test bona fide prospects.

Maps and information on oil and gas wells in the CDCA were obtained from the California Division of Oil and Gas. Well histories were obtained from Munger Service of Los Angeles. These data are summarized in Table A - 2.

The well summaries, as provided by Munger Service (Reference 25), yield relatively little geological information. Lithologies encountered in drilling are listed in a few of the summaries, but are absent from most. We presume that the intervals penetrated by most of the exploratory wells consist of Tertiary and Quaternary nonmarine sediments (principally sand and gravel, silt and clay). Some of the wells went to basement, encountering granite or other lithologies. The fact that oil and gas shows have been encountered in several wells is proof of the presence of oil and gas in the region, but the mere presence of shows should not be taken as a suggestion that commercial quantities of oil and gas exist. The oil and gas potential of the CDCA as a whole can best be estimated by comparison with other regions of generally similar geology. For example, in Nevada, which overall is somewhat comparable geologically to the CDCA, oil is present in Railroad Valley which lies roughly equidistant between Tonopah and Ely. The oil occurs in Tertiary valley fill sediments which overlie fractured volcanic flows and ash units. The oil is contained within the fractures in the volcanic rocks. There are large volumes of Tertiary and Quaternary sediments in the intermontane valleys of the CDCA. Presence of oil and gas in a similar environment in Nevada suggests that much of this material may have some oil and gas potential, but there is no way to assess this potential accurately. (Also the East Mojave area vs. overthrust belt.) PEMEX (Petroleo Mexicano or the Mexican National Petroleum Company) made a commercial gas strike in May, 1981 at 13,500 feet 30 miles south of Mexicali. The marine Miocene rock units which contain the PEMEX well are known to exist in the Imperial Valley of California.

CO_2 WELLS

There are eight CO_2 wells in the CDCA. All the CO_2 wells did plug - up with calcite in the 1960's. Due to the economics of the dry ice plant at Niland, the operation was closed down and abandoned as being unprofitable. The CO_2 is used primarily for the production of dry ice. CO_2 well summaries were provided by Munger Service. The information is summarized in Table A - 3.

GEOTHERMAL WELLS

Information on geothermal development was obtained from Munger Service; the California Division of Oil and Gas; the USGS "Geothermal Land Classification Map for California - Southern Half"; the Bureau of Land Management, Bakersfield; and the California Energy Resource Conservation and Development Commission (CERCDC), Geothermal Office. A large portion of the CDCA has been designated as either a "Known Geothermal Resource Area" (KGRA) or a "Valuable Prospective Area" by the USGS.

The CERDC estimates that geothermal power production in the CDCA will be up to 900 MW by the year 1990*. The forecast of 900TMW results from production from five KGRA's located in the CDCA: Brawley, Heber, East Mesa, Salton Sea Westmoreland and Coso. The last KGRA, Coso, has now five producible wells on Navy administered land. Of the five, one well is dry steam and the other four have dual phase fluid, that is steam and hot water. All Coso wells are less than 2,000 feet deep. The Navy has announced plans to build in 1983 a 35 MW plant supplied by these five wells.

Table A - 4 lists geothermal wells in the CDCA as of February 1981. As indicated by the number of potentially productive wells, the estimate of geothermal power production may be achieved given adequate power plant development and the continuation of drilling activity.

Table A - 5 summarizes the status of geothermal power plant development in the CDCA. At present, there ar two plants operating. In addition, two geothermal power plants of approximately 50 MW capacity are planned and one other 50 MW plant is under construction.

The Department of Energy (DOE), in conjunction with San Diego Gas and Electric Company, operates a test plant for research on the problems of the corrosive, high - solid geothermal fluids found in the Salton Sea geothermal reservoir. Following the resolution of the technical and funding problems, the test plant will become an operational plant.

A 10 MW capacity plant is planned in the Salton Sea area contingent upon the resolution of the technical problems associated with high - solid and corrosive geothermal fluids.

BLM has prepared an environmental impact statement for the lease of about 70,000 acres of federal land in the Coso Hot Springs area for geothermal development. In addition, the U.S. Navy is evaluating the use of geothermal energy for its facility at the China Lake Naval Weapons Center. The EIS assumes development of a total of 550 MW of electricity generating capacity. The EIS was finalized in September, 1980 and Coso was leased in September 1981.

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* Woody Ennis, California Energy Resources Conservation and Development Commission, Geothermal Office, Sacramento, July 23, 1979.

TABLE A - 2

Summary Of Exploratory Wells Drilled For Oil And Gas In The CDCA†

UTM Coordinate	Operator	Lease	Well Number	Year Start	Year Complete	Elevation (feet)	Total Depth (feet)	Location	Shows Reported	Depth Basement Encountered (feet)
PK 4424	Major Oil Corporation	Ramseyer	1-35	1973	1973	2660RT	3477	35-16N-15E	3200': ± 100' of thinly embeded oil sand	
PK 6026	Major Oil Corporation	Thompson	63A-30	1971	1977	2977KB	827	30-16N-16E		
MK 0814	Wm. Bosustow Company				1916		4060	27-29S-37E MD*		
PK 5024	Ivanpah Oil Association	Ivanpah	1	1940	1962	2600GR	2211	23-15½N-15E	1900': Gas Reported	
PK 5024	Major Oil Corporation	Ivanpah	2-23	1972	1972		1870	23-15½N-15E		
NK 7616	The Arapahoe Petroleum Co.		1	1925	1925	916GR	190	8-15N-8E		190'
PK 4214	Emmett J. Culligan	Culligan	1	1966	1966	3363RT	2145	24-15N-14E		
PK 4814	Major Oil Corporation	Ivanpah	1-23	1971	1971		2440	23-15N-15E MD	940'-1060': Oil Showings	
MK 1208	Western Research Lab. Inc.	Crook Shank	A-1	1949	1949	2234RT	1821	13-30S-37E MD		
MK 1208	Red Rock Company	Red Rock	1	1940	1940	2253	2942	13-30S-37E MD		
MK 0804	Crown Drlg. Company	Rancho Rico	1	1953	1953	2063KB	4760	27-30S-37E MD		
MK 0804	Alvern Pet. Company	Alvera	1		1953		700	27-30S-37E MD*		
MK 1206	J & S Exploration Company	Crook Shank	2	1944	1944	2190GR	2883	19-30S-38E MD		
MK 1206	J & S Exploration Company	Crook Shank	3	1944	1944	2125GR	2950	19-30S-38E MD		
MK 1408	Red Rock Oil Company, Inc.				1926		2727	19-30S-38E MD*		
MK 1206	Chas. W. Harlow				1926		5065	30-30S-38E MD*		
MJ 0896	Blake, Thomas M.	Cinco	1	1944	1945	2230GR	1718	22-31S-37E MD	985' - Oil Sand 1435' - Gas 1495' - Oil and Gas	
MJ 0896	Cinco Development Company	Hix	1	1946	1947	2225GR	1440	22-31S-37E MD		
MJ 1096	Park, T. L.(P&H Oil Co.)	Dove	1	1945	1945	2200Gr	60	25-31S-37E MD		
MK 1400	Geo. A. Parsons		1		1924		151	15-31S-38E MD*		
MJ 1496	Fremont Oil Corporation		1		1924		1440	22-31S-38E MD*		
MJ 1496	Fremont Oil Corporation		2		1926		2620	22-31S-38E MD*		
LJ 8694	Paul Beamer	Well	1	1948	1949	2934DF	1825	20-32S-36E MD		
MJ 0690	J. S. & L. Company	Childs-Wall	1	1945	1947	2465GR	2266	9-32S-37E MD	1351' - Oil (few) 1460' - Oil Shows 1220-1240'	
MJ 0890	National Security Oil		1		1921		111	11-32S-37E MD*		
MJ 2690	J. E. Johnson	M & R	1	1946	1947		2422	9-32S-39E MD		1379'
MJ 7488	Joshua Hills of Calif.	Ricky	1	1957	1958	2800GR	210	16-32S-44E MD		
MJ 7484	Herbert A. Schesler	Pyramid-Schweitzer	1	1969	1970	2450GR	4046	28-32S-44E MD		3170'
MJ 7082	Fremont Development Co.	Fremont	1	1952	1952	2300GR	2468	34-12N-4W		2650'
LJ 9880	Beamer, Paul (Newton Oil Company)	Oswald	1	1945	1950	2500GR	1092	12-11N-12W		
LJ 9678	Mojave Oil Company		1		1916		1040	14-11N-12W *		
MJ 0676	B.C. Mackey		1		1926		678	23-11N-11W *		
MJ 0676	P. Ray Asmussen & Assoc.		1		1927		1512	23-11N-11W *		
MJ 2276	Kendall Dev. Company, Ltd.		1		1932		1345	27-11N-9W *		
MJ 6274	Myron T. King	Alicia	1	1959	1959	2386KB	3553	28-11N-5W		3150'
MJ 7270	Trumpet Resources Dev. Co.	Lynx Cat Mountain	1	1968	1968	2261GR	1817	34-11N-4W		
MJ 7070	O.M. Lowell	Chicago Barstow Oil	1	1913	1913	2200	2700	35-11N-1W		2700'
NJ 8876	Mizpah Oil Company	16	1	1923	1923	1188GR		16-11N-9E		
PJ 1074	Harding, John B.	Harding	2	1911	1911		1512	23-11N-11E		

TABLE A - 2

Summary Of Exploratory Wells Drilled For Oil And Gas In The CDCA[†]

(Continued)

UTM Coordinate	Operator	Lease	Well Number	Year Start	Year Complete	Elevation (feet)	Total Depth (feet)	Location		Shows Reported	Depth Basement Encountered (feet)
LJ 7666	Willow Springs Oil Company	Lucky Strike	1		1938		4126	27-10N-14W	*		
LJ 7864	Regina Oil Corp., Ltd.	Marsh	1		1934		3267	35-10N-14W	*		
MJ 1272	John B. Harding		2		1932		1104	5-10N-10W	*		
PJ 1074	John B. Harding	Harding	5		1928		1048	5-10N-10W			
MJ 1268	Crusaders Oil		1		1924		1200	21-10N-10W	*		
MJ 5070	George H. Marsh	Well	1	1948	1948	2503	1272	5-10N-6W			1272'
MJ 6670	G. A. Grober & Associates	Well	2	1955	1956	2260KB	1877	1-10N-5W			1877'
MJ 6470	Interstate Oil Corporation	Kraemer	3	1924	1924	2200	2947	2-10N-5W			2947'
MJ 6470	Mojave Basin Oil Company	2	1	1924	1924	2223	700	2-10N-5W			
MJ 6470	Jack Radovich	Radovich	1	1950	1952	2250GR	3160	3-10N-5W		3160' - Gas Showings	3164'
MJ 5870	L.A. Thomson	Thomson-Cimarron	1	1963	1963	2513KB	3500	7-10N-5W			
MJ 6470	Equitable Pet. Explor. Co.		1	1935	1937		3042	11-10N-5W		938' - Oil & Gas 1341' - Oil & Gas 1999' - 1.99% Oil	2864'
MJ 6670	G. A. Grober & Associates	Well	1	1953	1956	2255RT	3124	12-10N-5W			3117'
MJ 6870	G. A. Grober & Associates	Well	3	1956	1956	2255KB	1242	7-10N-4W			1242'
NJ 3870	Western Pacific	Well	3	1929	1933	1780GR	3417	4-10N-4E			
NJ 3870	Western Pacific	4	3	1925	1925	1765GR	3397	4-10N-4E			
NJ 3870	Western Pacific	4	1	1922	1922	1760GR	2510	4-10N-4E			
NJ 3670	Sierra Oil & Gas Company	Wilhelm	1	1959	1961	1750GR	6404	5-10N-4E			6404'
PJ 9868	Flamingo Oil Company	Flamingo	1	1957	1960	1710KB	2680	18-10N-21E		Showings 2000 - 2200'	
LJ 4854	Robert Watchorn		1		1919		4150	27-9N-10W	*		
LJ 6860	Meridian Oil Company		1	1930	1933		3970	11-9N-15W		3930' - Showing Oil	3902'
LJ 9254	Ebert & Brandt	C. L. Wilson	1	1967	1968	2323KB	2233	32-9N-12W			
MJ 1860	Kern Torrence Pet. Corp.		1		1925		500	13-9N-10W	*		
MJ 6256	H. A. Pagenkopf	Emcap	1	1949	1951	2670GR	2780	22-9N-5W			2542'
LJ 4650	John Q. Tannehil	Community	1	1954	1955	2994RT	1325	10-8N-17W			
LJ 6052	William J. Stava	Gorrindo	1	1957	1957	2804RT	1315	1-8N-16W			
LJ 6652	Fairmont Exploration Co.	Lane	1	1958	1958	2670KB	2200	3-8N-15W			
LJ 6652	C. F.Staiger & L. A. Freemen	Scott	10-1	1950	1951	2657GR	3050	10-8N-15W			
LJ 7048	Solar Oil Company, Inc.	Singer	1	1950	1950	2445GR	2090	13-8N-15W			
LJ 6446	H & K Exploration Company	Ben Hur	87-21	1950	1950	2835KB	3430	21-8N-15W			
LJ 6244	San Roque Oil & Expl. Co.	Skelton	1	1961	1961	3267DF	3155	31-8N-15W			
LJ 6844	Antelope Oil Company	Ouhart	1	1940	1940	2700	2050	36-8N-15W			
LJ 9852	Morris B. Barks	Gloria	1	1950	1950	2304GR	1256	2-8N-12W			
LJ 9846	George A. Oenison		1		1921		1000	24-8N-12W	*		
MJ 0450	Rosamond Oil Company	Houston	3	1950	1950	2300 (topo)	1387	15-8N 11W			
MJ 0252	C. W. Colgrove	Hughes	11-9	1952	1952	2300GR	5576	9-8N-11W			
MJ 3044	Lehr Company		1		1945		880	33-8N-8W	*		
MJ 3044	Lehr Company	Lehr	2	1946	1946	3000	1000	33-8N-8W			
MJ 5650	Adelanto Development Corp.	Adelanto Oil Well	1	1954	1955	3006RT	4500	12-8N-6W		2400' - Gas and Oil	3951'
MJ 5850	Adelanto Oevelopment Corp.	G	3	1956	1956	300GR		7-8N-5W			2539'
MJ 6448	Adelanto Oevelopment Corp.	Adelanto	G-2	1955	1955	2850GR	2100	14-8N-5W			2100'
NJ 3848	Allen-Weiss & Associates	Hosterman	1	1955	1955	1803RT	1700	17-8N-4E			
LJ 7442	H. W. Shaffer	Munz	1	1951	1952	2569KB	4428	9-7N-14W			4428'
LJ 7838	C. W. Colgrove	Schwandt	57-23	1951	1951		3153	23-7N-14W			3153'
LJ 7436	Barnes Core Orilling Co.	McNaughton	1	1965	1965	2804KB	465	28-7N-14W			
LJ 8836	Oel Sur Oil Company	Oel Sur	1	1945	1946	2500	4106	26-7N-13W			
LJ 8636	COMCO	Godde	1	1959	1959	2400GR	2129	27-7N-13W			2129'

TABLE A - 2

Summary Of Exploratory Wells Drilled For Oil And Gas In The CDCA†
(Continued)

UTM Coordinate	Operator	Lease	Well Number	Year		Elevation (feet)	Total Depth (feet)	Location	Shows Reported	Depth Basement Encountered (feet)
				Start	Complete					
LJ 9844	H. B. Proctor	Comer	1	1955	1955	2361DF	1500	1-7N-12W		
LJ 9640	Antelope Oil & Gas Co.		1		1921		1640	11-7N-12W	*	
LJ 9640	Antelope Oil & Gas Co.		2		1925		1905	11-7N-12W	*	
MJ 0044	Cedric E. Brown Gas & Oil Company, Inc.	Well	1	1956	1956	2359RT	3440	5-7N-11W		
MJ 0044	Cedric E. Brown Gas & Oil Company, Inc.	Well	2	1956	1958	2359RT	3040	5-7N-11W		
MJ 0238	John B. Harding	La Loma	1		1927		973	28-7N-11W	*	
MJ 1640	D. H. Wood	5	2	1927	1927	2465GR	850	5-7N-10W		
MJ 1044	D. H. Wood	5	1	1927	1927	3000GR	795	5-7N-10W		
MJ 2636	Citizens Oil & Land Corp.		1		1922		100	36-7N-9W	*	
MJ 2842	James F. Whitehorn	Whitehorn-Card	1	1952	1952	2075GR	330	7-7N-8W		
LJ 8430	Farned, LeValley & Greer	Ritter	1	1951	1951		850	15-6N-13W		
LJ 9032	Anapola Oil Corporation	Well	1	1946	1947	2540	1762	6-6N-12W	1750' - Oil & Gas Showings 840-910'	
LJ 9432	John B. Harding		1		1925			9-6N-12W	*	
LJ 9230	New Cal Oil Company	Well	1	1939	1939		1219	17-6N-12W	1219' - Oil & Gas 845-1170'	
LJ 9230	Antelope Valley Pet. Co.	Well	1	1937	1938		1070	17-6N-12W	1070' - Oil & Gas	
MJ 0624	Christenson, Roy M.		1	1922	1931		1100	34-6N-11W		
MJ 1628	Butte Petroleum Co., Inc.	Ruby	1	1960	1961	2745GR	3805	26-6N-10W		
MJ 3226	Walter Siravo	Ralph Arnold	1	1950	1950		830	27-6N-8W		
MJ 4626	A. C. Anderaon	Black Butte	1	1949	1950	3000GR	3092	26-6N-7W	2201' - Oil & Gas 2085-2105'	3092'
MJ 6232	A. B. Clark & C. E. Huntoon	Mutz	1	1952	1953	2800GR	200	4-6N-5W		
MJ 6626	Mojave River Oil Company	Well	1	1920	1920	2800GR	816	25-6N-5W		
MJ 7224	H. T. Widney & G. G. Widney	Well	1	1949	1949	3000GR	520	33-6N-4W		370'
LJ 9824	Wright Oil Tool Company	Wright	1	1937	1937	2750GR	1420	1-5N-12W		
MJ 0024	Lindsey, R.S.	Ballentine	1	1937	1938		1710	1-5N-12W		
MJJ0024	Dillar, William S.	Lindsey	1	1937	1937		1135	1-5N-12W	1135' - Oil	
LJ 9224	Silver Leaf Oil Company	Realty Title Co.	1	1950	1950	2500GR	635	5-5N-12W		
LJ 9224	Raymond D. Weller	Well	1	1950	1950		1281	5-5N-12W		565'
MJ 0818	J. E. Willette	Chief Paduke	1	1952	1952	3200DF	1450	24-5N-11W		
MJ 1418	Socony Mobil Oil Co., Inc	Was	1	1939	1940	65GR	5955	21-5N-10W	5790' - Faint Cut	
MJ 1418	Orlando Oil Corporation	Orlando	1	1948	1948	3402	1345	32-5N-10W		
MJ 2218	Willette Oil Company	Virginia Lee	1	1944	1947	3175DF	3900	20-5N-9W	3394-3404' - Petroleum Odor	3573'
MJ 3218	J. B. Halbert	Houston	1	1950	1950	3265GR	600	15-5N-8W		
MJ 5418	Victor Valley O&R Co.	Victor	1	1931	1931	3500	3216	22-5N-6W		
NJ 0618	Lucerne Valley Exploration Company, Ltd.	Laurabel-Norman	1	1955	1955	2865RT	657	19-5N-1E	657' - Oil & Gas 625-650'	657'
MJ 4608	Alton Oil & Development Co.	Handley	1	1955	1956	4433KB	6365	23-4N-7W	5500' - Oil & Gas	3700'
MJ 4808	Richard Oil Company	Nielson	1	1956	1956	4505DF	4011	24-4N-7W	2800' - Oil & Gas	
MJ 6610	Rex Oil Company	Justice	1-B	1950	1950	3500GR	3096	13-4N-5W		
MJ 6404	Ute Oil Company	Lee Salter	1	1944	1944	3700	2802	34-4N-5W		
MJ 7006	Hesperia Oil & Gas Company of California	29	1	1924	1924	3375GR	3103	29-4N-4W		
MJ 7006	Hesperia Oil & Gas Company of California	29	1-A	1925	1925	2960GR	3316	29-4N-4W		
MJ 8012	B.K.E. Drlg. & Prd. Co.	Inland	1	1940	1940	3000	250	4-4N-3W		
MJ 8012	Albert Crooks	Inland	1	1940	1940	3000GR	1335	4-4N-3W		1310'

TABLE A - 2

Summary Of Exploratory Wells Drilled For Oil And Gas In The CDCA[†]

(Continued)

UTM Coordinate	Operator	Lease	Well Number	Year		Elevation (feet)	Total Depth (feet)	Location	Shows Reported	Depth Basement Encountered (feet)
				Start	Complete					
MJ 8010	The Ord Oil Company	Ord	1	1954	1955	3006KB	3097	9-4N-3W		3086'
NJ 0210	Verne Chute	Lucerne Valley	1	1936	1936	3000GR	1745	14-4N-1W		1745'
MJ 9808	Allied Petroleum Corp.	Chief	1	1947	1951	2990	1850	17-4N-1W	1510' - Oil & Gas	1347'
MJ 9808	Moore & Peterson	Lucerne Valley		1932	1932		1512	17-4N-1W		
MJ 9808	Paul M. Peterson	Moore	1	1931	1932	3000GR	1544	17-4N-1W		
MJ 6400	Cajon Basin Company	Carver	1	1954	1954	3500GR	1428	14-3N-5W		1428'
NH 5486	Retari Company, Inc.	Retari	1	1953	1954	3856GR	1311	25-2N-5E	1265-1311' - Oil	
NH 7486	Oro Negro Oil Company	Onoco	1	1962	1962	2308RT	2106	28-2N-8E	1792'	2106'
NH 8880	W. E. David	21	1	1966	1966	2005KB	1472	21-1N-9E		
NH 9278	Custom Drilling Company	Bergman	1	1957	1957	2005KB	425	24-1N-9E		
NH 9676	Lee Oil Development	Lee Oil	1	1975	1975	1846KB	1715	29-1N-10E		1715'
NH 3458	Painted Hills Oil Assoc.		1	1920	1920	200GR	1250	25-2S-3E		
NH 3658	Painted Hills Oil Assoc.		2	1921	1921	1900GR	350	30-2S-4E		
NH 3454	C & K Oil Company	Moore	1	1955	1956	1677KB	868	1-3S-3E		
NH 3254	Parsons Petroleum Company	Well	1	1962	1963	1635KB	460	2-3S-3E		
NH 3054	Cabazon Central Oil Co.	9	1	1922	1922	1200GR	700	9-3S-3E		
NH 4054	Western Development Corp.	4	1	1921	1921	1130GR	975	4-3S-4E		
NH 5248	The Texas Company	Stone (NCT-1)	1	1953	1954	1512GR	7474	35-3S-5E		
NH 7234	CHS Company, Ltd.	Bobbie	1	1950	1951	-17GR	1901	11-5S-7E		
PH 0210	Spindletop Oil Syndicate	Salton Sea	1	1929	1933	150GR	3812	25-7S-10E	3812' - Slight Shows of Oil & Gas	
NG 9282	The Pure Oil Company	Truckhaven Unit	1	1944	1944	99	6100	26-10S-9E	4020' - Gas	6039'
PG 3282	E. J. Piatt		1	1933	1933	-160GR	173	24-10S-13E		
NG 8462	Oklahoma Oil Company	Well	1	1931	1934		213	25-11S-8E		
NG 8470	San Felipe Oil Company	Dauner	1	1932	1933	175GR	847	25-11S-8E		
NG 9270	Diamond Bar Oil Company	Well	1	1950	1950		3085	25-11S-9E		
NG 9270	Jesse M. Nelson	25	1	1920	1920	100GR	3085	25-11S-9E		
NG 9072	Standard Oil Company	Southern Land Company	1	1944	1944	57GR	4531	27-11S-9E	3293' - Gas	4531'
PG 0076	Mortimer & Rasmussen	Truckhaven	1	1950	1950	-115GR	2543	10-11S-10E		
NG 9470	Texaco, Inc.	Pure (NCT-1)	1	1951	1952	162GR	4414	31-11S-10E		
NG 9868	Imperial Valley Oil & Development Association	32	1	1919	1930	100GR	2800	32-11S-10E		
NG 9868	Imperial Valley Pet. Co.	Well	1	1929	1930	150GR	4160	33-11S-10E		
PG 5678	Barth Oil Company, Inc.	Barth	1	1934	1942	750GR	2855	5-11S-16E	1635-1645', 1734-1746', 2467-2507', 2520-2525', 2552-2555': Oil & Gas; 2708-2720': CO_2	
PG 5276	D. H. Wood	Melson	1	1931	1931	650GR	900	7-11S-16E		
PG 5476	Irex Oil Company	7	1	1947	1947	650GR	1375	8-11S-16E		
QG 0478	Bernard J. Patton	Midway Well	1	1960	1961	565DF	3809	6-11S-21E	880-1050': Light Oil & Gas	
QG 0478	Campbell, Egger & Rottman	Federal	1	1953	1954	575GR	1320	6-11S-21E	1080' - Swabbed a little Oil	
NG 8268	John F. Sheran	Sheran	1	1930	1940	180GR	3912	3-12S-8E		2100'
PG 3264	Sardi Oil Company	Biff	1	1960	1962	-166GR	6350	24-12S-13E		
PG 3654	Amerada Hess Corporation	Veysey	1	1944	1945	150	8350	9-13S-14E		
PG 6858	Ajax Oil & Development Co.	USL Phillis	1	1955	1955	272KB	3315	2-13S-17E		
PG 1648	Texaco, Inc.	Brawley Unit Stipek	1	1952	1952	112GR	8647	4-14S-12E		
PG 4440	Chevron	Wilson (et al.)	1	1963	1963	-110DF	13443	20-14S-15E		
PG 5842	104 Oil & Drilling Co.	11	1		1925		1911	14-14S-16E		
PG 5842	104 Oil & Drilling Co.	11	2		1926		2400	14-14S-16E		
PG 5844	104 Oil & Drilling Co.	11	3		1927		989	14-14S-16E		
NG 8434	Carrizo Valley Oil Corp.	Well	1-13	1956	1956	563GR	900	13-15S-8E		

TABLE A - 2

Summary Of Exploratory Wells Drilled For Oil And Gas In The CDCA[†]

(Concluded)

UTM Coordinate	Operator	Lease	Well Number	Year		Elevation (feet)	Total Depth (feet)	Location	Shows Reported	Depth Basement Encountered (feet)
				Start	Complete					
PG 6832	American Petrofina Exploration Company	U.S.A.	27-1	1966	1966	101KB	10550	27-15S-17E		
NG 9826	San Diego & Imperial Valley Oil Company		1		1928		2500	9-16S-10E		
PG 0428	Southwestern Petroleum & Pipeline Company		1		1925		700	6-16S-11E		
PG 3620	Amerada Hess Corporation	Timken	1	1945	1945		7323	28-16S-14E		
PG 1428	Texaco, Inc.	F. D. Browne	1	1952	1952	34GR	7808	6-16S-12E		
PG 5424	Texaco, Inc.	Grape Ergebretsen	1	1944	1945	8GR	12313	8-16S-16E		
PG 6624	H. W. Schafer	Barbara	1	1958	1960	94KB	8017	16-16S-17E		
QG 0028	Andrew J. Crevolin	Betsey Russ	1	1956	1957	250GR		3-16S-20E		
NG 9818	Petrodynamics Association	Straw	1	1964	1968	378DF	4008	2-17S-10E		
PG 0412	DeAnza Oil Company, Ltd.	F.G.W. deAnza USL	1	1959	1959	377KB	1245	20-17S-11E	1050' - Minor Shows	
PG 0412	J. B. Nelson	Snow Government	1	1967	1968	0	1160	20-17S-11E		
PG 0412	Clarence E. Harrison	Yaha	1	1961	1968	354RT	3210	20-17S-11E		
PG 0412	Mike Barkett	Barkett	2	1962	1968	350RT	1200	20-17S-11E	395' - Oil, 490-520': Thin Oil, 640-700' and 740-855': Oil & Gas Shows Increased	230'
PG 3214	Texaco, Inc.	Jacobs NCT-1	1	1951	1951	10GR	7505	18-17S-14E		

Note: Source is Munger (Reference 25) unless otherwise indicated by asterisk. San Bernardino is Base Meridian (except where indicated by MD = Mount Diablo).

* Source: California Division of Oil & Gas, Maps (See bibliography)

† As of November, 1977

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Summary Of Exploratory Wells Drilled For CO_2 In The CDCA[†]

UTM Coordinate	Operator	Lease	Well Number	Year		Elevation (feet)	Total Depth (feet)	Location
				Start	Complete			
PG 9618	Pacific Dry Ice Company	Pacific Dry Ice	1	1946	1946	-150GR	1505	9-9S-12E
PG 9620	Pacific Dry Ice Company	Pacific Dry Ice	2	1946	1946	-150	1510	11-9S-12E
PG 9620	Pacific Dry Ice Company	Pacific Dry Ice	3	1947	1947	-150GR	1560	11-9S-12E
PG 9620	O'Quinn & Hadley	All American Acres Comm.	1	1944	1944	-125	1452	11-9S-12E
PG 3080	Anthony Rivers Dev. Co.	Anthony	1	1945	1945	-237GR	533	34-10S-13E
PG 3078	Cardox Corporation	Well	B-9		1941		860	3-11S-13E
PG 3076	Cardox Corporation	Well	B-8		1941		860	11-11S-13E
PG 3472	J. P. Chandler & Lee Station	19	1	1935	1935	220GR	590	19-11S-14E

Note: Source is Munger (Reference 25).
San Bernardino is Base Meridian.

† As of November, 1977

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Summary Of Exploratory Geothermal Wells In The CDCA

UTM Coordinate	Operator	Lease	Well Number	Year Start	Year Complete	Elevation (feet)	Total Depth (feet)	Location*	Remarks
PG 1648	Magma Energy, Inc.	Bonanza	1	1973	1975	-51KB	5024	22-15S-14E	Abandoned
PG 2298	Q. B. Resources International	1	1	1973	1973	-63KB	1695	1-9S-12E	
PG 2416	Magma Energy, Inc.	Fed-Rite	1	1973	1973	-8KB	5100	8-17S-13E	
PG 2462	Magma Energy, Inc.	Dearborn	1	1972	1972	215KB	4135	30-12S-13E	Unsatisfactory
	Republic Geothermal, Inc.	Dearborn Farms	1	1976	1976	-200KB	8000	30-12S-13E	Potential Producer
	Republic Geothermal, Inc.	Dearborn	2	1976	1977	-213FR	4564	30-12S-13E	Potential Producer
PG 2660	Republic Geothermal, Inc.	Kulln Farms	1	1976	1976	-59KB	8490	32-12S-13E	Potential Producer
PG 2664	Republic Geothermal, Inc.	Landers	1	1976	1976	-202KB	7705	20-12S-13E	
	Republic Geothermal, Inc.	Landers	2	1976	1976	-202KB	7507	20-12S-13E	Potential Producer
	Republic Geothermal, Inc.	Landers	3	1976	1976	-202KB	4650	20-12S-13E	Potential Producer
	VanHeisen and Griffen	Grace	1	1963	1963	202KB	1200	19-12S-13E	
PG 2670	Imperial Magma	MAGMAMAX	2	1972	1974	-239KB	4305	33-11S-13E	
	Salton Sea Chemical Products		1		1932		1050	28-11S-13E	(Source: DOG G2-1)
PG 2868	Geothermal Energy & Mineral Corporation	Sinclair	1	1957	1958	-215KB	4680	10-12S-13E	
	Geothermal Energy & Mineral Corporation	Sinclair	2	1961	1961	-220	2368	4-12S-13E	
	Geothermal Energy & Mineral Corporation	Sinclair	3	1962	1973	-220GR	6972	10-12S-13E	
PG 2870	Union Oil Company	J. J. Elmore	1	1964	1964	-225GR	7117	27-11S-13E	Producer
	Imperial Magma	Elmore	3	1974	1975	-227	2510	27-11S-13E	Potential Producer
	Imperial Magma	MAGMAMAX	1	1971	1975	-214KB	2800	33-11S-13E	
	Imperial Magma	MAGMAMAX	3	1972	1974	-238KB	4000	33-11S-13E	
	Imperial Magma	MAGMAMAX	4	1972	1972	-238KB	2560	33-11S-13E	500-550 °F Bottom
	Imperial Magma	Woolsey	1	1972	1975	-213KB	2400	33-11S-13E	
PG 2876	Pioneer Development Company		1		1927		675	10-11S-13E	
	Pioneer Development Company		2		1927		1200	10-11S-13E	
	Pioneer Development Company		3		1927		1400	10-11S-13E	
PG 3072	Shell Oil Company	State of California	1	1964	1964	-218DF	4859	23-11S-13E	
	Imperial Thermal Products	Imperial Irrigation District	2	1963	1977	-200GR	5826	22-11S-13E	
	Imperial Thermal Products	Imperial Irrigation District	1	1962	1966		5230	23-11S-13E	113,400#/hr. steam 423,600#/hr. water Wellhead pressure 182 psig
	Imperial Thermal Products	Imperial Irrigation District	3	1965	1975		1200	23-11S-13E	
	Imperial Thermal Products	Sportsman	1	1961	1961	-214KB	4736	23-11S-13E	57,000#/hr. steam 209,000#/hr. water Wellhead 200 psig, 390°F
PG 3216	Union Oil Company	Bacon	1	1976	1976	2KB	4037	7-12S-14E	
PG 3272	Salton Sea Chemical Products		5		1933		900	24-11S-13E	(Source: DOG G2-1)
PG 3274	Union Oil Company	Hudson	1	1964	1964		6141	13-11S-13E	Successful Steam Well
	Union Oil Company	River Ranches	1	1963	1963	-211KB	8100	24-11S-13E	100 psig Wellhead 800°F Bottom
PG 3420	New Albion Resources Company (Magma)	Heltz	2	1972	1972	2KB	5000	31-16S-14E	

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Summary Of Exploratory Geothermal Wells In The CDCA

(Continued)

UTM Coordinate	Operator	Lease	Well Number	Year Start	Year Complete	Elevation (feet)	Total Depth (feet)	Location*	Remarks
PG 3454	Chevron USA, Inc.	Rutherford	1	1977	1977	-127KB	7930	8-13S-14E	Potential Producer (Source: DOG)
PG 3618	Union Oil Company	Thomson	1	1976	1976	10KB	7132	4-17S-14E	
PG 3620	Magma Energy, Inc.	Holtz	1	1972	1972	2KB	5147	32-16S-14E	Potential Producer (Source: DOG)
	Magma Energy, Inc.	Holtz	2	1972	1972	2KB	5000	32-16S-14E	Potential Producer (Source: DOG)
	Chevron Oil Company	C. B. Jackson	1	1974	1974	7KB	5968	32-16S-14E	Potential Producer (Source: DOG)
	Chevron Oil Company	Nowlin Partnership	1	1972	1972	7KB	5030	33-16S-14E	Potential Producer (Source: DOG)
	Chevron Oil Company	J. D. Jackson, Jr.	1	1974	1974	7KB	6046	33-16S-14E	Potential Producer (Source: DOG)
PG 3622	Chevron Oil Company	Hulse	1	1974	1974	7KB	6400	29-16S-14E	Potential Producer (Source: DOG)
PG 3640	Chevron Oil Company	Mercer	1-28					30-14S-14E	
PG 3652	Chevron Oil Company	Brandt	1	1978	1978	-136KB	10019	17-13S-14E	Potential Producer (Source: DOG)
	Union Oil Company	H. B. Tow	1	1975	1975	-128KB	5031	16-13S-14E	Potential Producer (Source: DOG)
	Union Oil Company	Veysey	7	1978	1978	-125KB	5688	16-13S-14E	Potential Producer (Source: DOG)
	Union Oil Company	Veysey	8	1978	1978	-125KB	8077	16-13S-14E	Potential Producer (Source: DOG)
	Union Oil Company	Veysey	9	1979	1979	-123KB	7908	16-13S-14E	Potential Producer (Source: DOG)
	Union Oil Company	Veysey	10	1979	1979	-122KB	6827	16-13S-14E	Potential Producer (Source: DOG)
	Union Oil Company	Kruger	1	1975	1976	-125KB	6793	17-13S-14E	Potential Producer
	Union Oil Company	Veysey	2	1975	1975	-133KB	5921	21-13S-14E	Potential Producer (Source: DOG)
PG 3818	Union Oil Company	Murdy	1	1976	1976	6KB	4263	10-17S-14E	
	Union Oil Company	Thomson	2	1975	1976	10KB	9701	3-17S-14E	Potential Producer
	Chevron Oil Company	GTW	5	1976	1976	9KB	7089	2-17S-14E	
PG 3820	Chevron Oil Company	34	GTW-3	1975	1975	0KB	3914	34-16S-14E	
	Union Oil Company	Saikhon	1	1975	1976	6KB	4500	34-16S-14E	
	Chevron Oil Company	27	GTW-1	1975	1975	0KB	3458	27-16S-14E	
PG 3822	Chevron Oil Company	27	GTW-2	1975	1975	0KB	3002	27-16S-14E	
PG 3838	McCulloch Oil Corporation	Mercer	2-28	1975	1975	-129KB		30-14S-15E	
PG 3854	Union Oil Company	Veysey	1	1975	1975	-129KB	8385	15-13S-14E	Potential Producer (Source: DOG)
	Union Oil Company	Cox	1	1974	1977	-477KB	9609	15-13S-14E	Potential Producer
	Union Oil Company	Jiminez	1	1974	1976	-150GR	9618	15-13S-14E	Producer
	Union Oil Company	Slater	1	1978	1979	-125KB	13097	14-13S-14E	Potential Producer (Source: DOG)
PG 4618	Republic Geothermal, Inc.	Silzle	1	1974	1975	30KB	11015	33-16S-15E	
PG 6028	Magma Energy, Inc.	Sharp	1	1972	1972	27KB	6070	35-15S-16E	
PG 5626							11600	8-16S-16E	320°F (Source: GLC)
PG 6226	Magma Power Company	Magma U.S.	44-7	1976	1976	30GR	7328	7-16S-17E	Potential Producer
	Magma Power Company		44A-7	1978	1978	30GR	7080	7-16S-17E	Potential Producer (Source: DOG)
	Magma Power Company		44B-7	1978	1978	30GR	6821	7-16S-17E	Potential Producer (Source: DOG)
	Magma Power Company	Magma U.S.	48-7	1976	1976	30GR	7523	7-16S-17E	Potential Producer
	Magma Power Company		48A-7	1978	1978	30GR	6916	7-16S-17E	Potential Producer (Source: DOG)
	Magma Power Company	Magma U.S.	46-7	1977	1977	42KB	3095	7-16S-17E	Potential Producer (Source: DOG)
PG 6228	U.S. Bureau of Reclamation	Mesa	6-2	1973	1973	26GR	6005	6-16S-17E	2350 psig, 280°F surface, Potential Producer (Source: DOG)
	U.S. Bureau of Reclamation	Mesa	6-1	1972	1972	34GR	8030	6-16S-17E	390-395°F Bottom, Producer
PG 6230	Republic Geothermal, Inc.	30	38-30	1975	1975	48KB	9009	30-15S-17E	Potential Producer (Source: DOG)
	Republic Geothermal, Inc.	30	30-7	1975	1977	165KB	7520	30-15S-17E	Capable
	Republic Geothermal, Inc.	30	30-5	1975	1977	50KB	8000	30-15S-17E	Potential Producer
	Republic Geothermal, Inc.	30	30-4	1975	1977	48KB	7439	30-15S-17E	Potential Producer
	Republic Geothermal, Inc		56-30	1977	1977	51KB	7520	30-15S-17E	Potential Producer (Source: DOG)
	Republic Geothermal, Inc.		16-30	1977	1977	49KB	8000	30-15S-17E	Potential Producer (Source: DOG)
	Republic Geothermal, Inc.		78-30	1977	1977	59KB	7442	30-15S-17E	Potential Producer (Source: DOG)
	Republic Geothermal, Inc.		58-30	1978	1978	56KB	7340	30-15S-17E	Potential Producer (Source: DOG)
	Republic Geothermal, Inc.		74-30	1979	1979	67KB	7659	30-15S-17E	Potential Producer (Source: DOG)
	U.S. Bureau of Reclamation	Mesa	31-1	1974	1974	51KB	6231	31-15S-17E	Potential Producer (Source: DOG)
PG 6232	Republic Geothermal, Inc.		56-19	1979				19-15S-17E	Potential Producer (Source: DOG)

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Summary Of Exploratory Geothermal Wells In The CDCA
(Concluded)

UTM Coordinate	Operator	Lease	Well Number	Year		Elevation (feet)	Total Depth (feet)	Location*	Remarks
				Start	Complete				
PG 6426	U.S. Bureau of Reclamation	Mesa	8-1	1974	1974	50MAT	6200	8-16S-17E	Potential Producer (Source: DOG)
PG 6428	U.S. Bureau of Reclamation	Mesa	5-1	1974	1974	71MAT	6016	5-16S-17E	300°F @ 4689', Potential Producer (Source: DOG)
PG 6430	Republic Geothermal, Inc.	28	18-28	1975	1976	18KB	8000	28-15S-17E	Potential Producer (Source: DOG)
	Republic Geothermal, Inc.	29	29-5	1975	1975		8021	29-15S-17E	
	Republic Geothermal, Inc.		16-29	1975	1975	65KB	8021	29-15S-17E	Potential Producer (Source: DOG)
	Republic Geothermal, Inc.		52-29	1977	1977	74KB	4524	29-15S-17E	Potential Producer (Source: DOG)
PG 8630	Dept. of Water Resources	Dunes	1	1972	1972	184KB	2016	33-15S-19E	218°F @ 850-590' 210°F @ approximately 600' 195-200°F @ 2000'
MK 2688	CER Corp. (Opr. for Navy)	CGEH	1		1977		4727	6-22S-38EMD	Temperature over 300°F @ 4043'
	Batelle Pacific N.W. Lab	Slimhole	1		1976			6-22S-38EMD	
MK 3220								12-29S-39EMD	80°F (Source: GLC)
MK 4814								28-29S-41EMD	81°F (Source: GLC)
MK 5014								26-29S-41EMD	205°F (Source: GLC)
MK 6868								9-24S-43EMD	137°F (Source: GLC)
PJ 9670							3086	18-10N-21E	109°F (Source: GLC)
PJ 1822							284	2- 5N-12E	84-89°F (Source: GLC)
NH 4654								5- 3S- 5E	200°F (Source: GLC)
NH 5054								10- 3S- 5E	200°F (Source: GLC)
NH 5252								14- 3S- 5E	Hot (Source: GLC)
NH 6842							360	9- 4S- 7E	120°F (Source: GLC)
NH 9622							864	19- 6S-10E	Hot (Source: GLC)

Note: Source is Munger (reference 25) unless otherwise indicated in remarks column.
DOG is California Division of Oil and Gas.
GLC is USGS Geothermal Land Classification Map.

* San Bernardino Base Meridian, except MD indicates Mount Diablo Base Meridian.

TABLE A - 5

Geothermal Power Plant Develpment In The CDCA

LOCATION	DEVELOPER	PLANT SIZE	GEOTHERMAL FLUID PRODUCER	SCHEDULED DATE OF OPERATION	STATUS	COMMENTS
Near Brawley	Southern California Edison (SCE)	10MW	Union Oil Company	1980	Completed June 1980	Operating at 10MW
East Mesa KGRA (East of Holtville)	Magma Power Company	10MW	Magma Power Company	1979	Completed in 1980 now operating at 8MW output	Pilot binary system plant. If proves successful, Magma Power and San Diego Gas & Electric have an agreement to expand the plant to 50MW; expected date of operation 1984.
East Mesa KGRA (East of Holtville)	Republic Geothermal, Inc.	19MW	Republic Geothermal, Inc.	1982	Permit approved 10/81	Binary Plant - will be combined with a block unit.
East Mesa KGRA (East of Holtville	San Diego Gas and Electric (SDG&E)	Department of Energy (DOE) Demonstration Project for Binary Cycle Plant.			Proposal abandoned January, 1979	Binary demonstration project in New Mexico initiated instead. Campaign underway to get DOE to sponsor a binary project for Imperial Valley to demonstrate the utilization of lower temperature resources.
Near Heber	SCE	50MW	Chevron, Inc.	mid 1982	Master Environmental Impact Report, finished in 1981	Flash Steam Unit approved. Construction has started.
Near Niland, Salton Sea	SDG&E and DOE	Test Plant 15MW	Magma Power Company	1982	Funding currently provided by SDG&E and DOE. SDG&E will abondon planned plant in September, 1979 if DOE does not agree to 100% financing of the facility.	New alloy of titanium, nickel and chromium for pipes has solved corrosive & clogging problems of using the geothermal fluids of the Salton Sea reservoir. These fluids have some of the highest known temperatures in the Imperial Valley but also have almost 25% solids.
	Republic and SDG&E	10MW	Republic	1985	In final approval process with CEC *	
South Shore Salton Sea	SCE	10MW	Union Oil Company	as early as 1983	Planned if problems with corrosive, high-solid fluids can be resolved.	

Sources: *California Energy Resources Conservation and Development Commission, Geothermal Office, Sacramento;
Los Angeles Times, 3 July 1979.

- APPENDIX B -

GEOLOGICAL, GEOPHYSICAL, GEOCHEMICAL TONAL ANOMALY AND LINEAMENT DATA FOR THE CDCA

I. INTRODUCTION AND SUMMARY

This geostatistical study requires systematic compilation of two categories of data, as follows:

1. Data on occurrences of mineral resources in the California Desert Conservation Area (CDCA).
2. Data on the geological, geophysical, geochemical, tonal anomaly and lineament characteristics of the CDCA.

The first category of data is described in Appendix A; this Appendix deals with the second.

In a general sense, geological, geophysical, geochemical, tonal anomaly and lineament data are used, along with known mineral occurrence data, for two purposes. First, they are used to develop statistical inferences about the likelihood of mineral occurrences in areas where no occurrences have been reported; and second, to assist with the expert panel classification. The statistical techniques and results are discussed in Appendix C.

An ideal set of geological, geophysical, geochemical, tonal anomaly and lineament data would include the following:

- Detailed, consistent geologic maps showing lithologic units and types and extent of faults.
- Detailed logs of exploratory wells for oil and gas, carbon dioxide, and geothermal fluids with information as to lithologic and formational units encountered.
- Consistent and current gravity and magetic data for the entire area.
- Uniform and accurately interpreted lineament data for the entire area.
- Uniform, consistent and accurate geochemical sampling data for the entire area.

Unfortunately, not all of these data are available within the CDCA. The following geological, geophysical, geochemical, tonal anomaly and lineament data were collected:

- Lithologic units, contacts between selected lithologic units, and faults from the Geologic Map of California of the California Division of Mines and Geology (CDMG), 1:250,000 scale (References 46 through 57). These data were encoded in numerical form.
- Gravity data provided for the CDCA by Dr. Shawn Biehler of the

University of California at Riverside, gravity data from the "Bouguer Gravity Map, Kingman Sheet" published by the California Division of Mines and Geology (Reference 59), and gravity data interpolated from the General Electric (GE) "Complete Bouguer Anomalies" contour map (Reference 78).

- Lineament data interpreted from LANDSAT imagery, Skylab and aerial photographs, and the Bouguer Gravity contour map by GE under contract to BLM (Reference 78).

- Reconnaissance level geochemical sampling data collected by BLM and analyzed by the USGS. BLM collected 2,500 samples from 1,250 locations. Sampling was concentrated in four areas of the CDCA (about 50 percent of the area). At each location, two samples were taken as follows: first, a sample was taken using ordinary methods and separated with a -500 micron mesh; second, a sample was taken and a heavy mineral concentrate was developed. Thus, there are two samples from each location — but each sample has a different characteristic. Semi-quantitative spectrographic analysis was performed to determine concentrations of 65 elements in each sample. These data are discussed in more detail in Section 4 of this appendix.

- Gamma-ray spectrometric and aeromagnetic data collected for the National Uranium Resource Evaluation (NURE) program of the Department of Energy covering the Kingman, Death Valley, Trona, Goldfield and Needles 1:250,000 quadrangles.

- Tonal anomalies detected on LANDSAT imagery by GE under contract to BLM (Reference 139, direct correspondence with Alan Smith at General Electric, Beltsville, Maryland). These tonal anomalies might be correlated with hydrothermal alterations.

The geologic and lineament data were compiled for each 2-km by 2-km square in the CDCA. There are 26,812 2-km by 2-km cells in the CDCA. The gravity data were compiled for each 4-km by 4-km square in the CDCA. The geochemical, tonal anomaly and aerial data were compiled for each 4-km by 4-km square where they were available. Once the data were compiled by hand and encoded onto a magnetic tape, they were merged into 4-km by 4-km cells for geostatistical purposes.

Tables 1, 2, 3, 4, 5, 6, and 7 of the main report list the geological, geochemical, geophysical, tonal anomaly and lineament variables used for the analysis. Sources of information including maps are listed in the reference section.

2. SELECTION OF GEOLOGIC AND GEOPHYSICAL VARIABLES

The geological and geophysical variables selected for encoding and subsequent analysis, listed in Tables 2, 3 and 4, were selected for two principal reasons:

1. The presence of these variables on the 1:250,000 CDMG Geologic Map of California, and

2. Their potential efficacy as measures of the regional geology, upon which subsequent statistical prediction of mineral occurrences have been based.

The variables listed in Table 2 are referred to by number for convenience. Variables 1 through 18 ("Lithologic units") have areal extent. Variables 19 through 33 ("Rock Contact Relationship"), 34 and 36 ("length of faults") have linear extent. The remaining variables (35 and 37 through 40) pertain to quantities that are neither linear nor areal. Variable 41, Bouguer gravity, is measured in milligals. Variable 42, the number of subcells, was used for computational convenience only.

As noted in Table 2, several lithologic units available from the geologic maps were combined into one variable for this study. For example, variable 4 is a combination of six lithologic units. These units were combined because they form similar environments for G-E-M occurrences. In addition, each variable used in geostatistical analysis should be present in sufficient quantity to be statistically meaningful. Several of the variables listed in Tables 2, 3 and 4, do not occur frequently enough to help in the geostatistical analysis. Two approaches exist to handle this problem and both were tried. One approach is to eliminate those variables that occur infrequently. The other approach is to combine low frequency variables with other similar ones. Low frequency variables were eliminated or combined on the basis of results of several tests. This is discussed in Section 3 of Appendix C.

3. SELECTION OF LINEAMENT VARIABLES

Lineaments are linear features identified on aerial photographs and/or satelite imagery. Some theories contend that lineaments represent the geologic parameter of crustal deformations that provide channels for mineralized solutions (Reference 79). It follows from this "hydrothermal plumbing system" theory that lineaments could play a role in determining mineral occurrence locations.

Lineaments are determined from an aerial view of the earth's surface by an experienced observer. The interpretation of lineaments is based upon what appears at the surface of the earth. The surficial features represent an integration of geologic time, with lineaments of various undifferentiated ages, all appearing on only one geometric plane — the earth's surface. This surface distribution may or may not be indicative of features at depth.

Lineaments were taken from maps prepared by GE under contract to BLM (Reference 78). Four classes of lineaments were mapped by GE as follows:

- Lineaments interpreted from LANDSAT imagery.
- Lineaments interpreted from aerial photographs.
- Lineaments interpreted from Skylab photographs.
- Lineaments interpreted from the gravity contour maps derived from data provided by Dr. Shawn Biehler at the University of California, Riverside.

For convenience of expression, lineaments interpreted from each of these four sources are identified throughout this report as lineaments of the particular source. For example, lineaments interpreted from LANDSAT imagery are subsequently referred to as LANDSAT lineaments.

The LANDSAT imagery and the gravity data are uniform and complete in their coverage of the CDCA. On the other hand, neither the Skylab nor the aerial imagery used to interpret lineaments was complete. Figure B-1 shows that the areas covered by aerial and Skylab imagery are almost mutually exclusive. In the few areas with overlap, there is little correlation between lineaments interpreted from the two sources. Thus, the Skylab lineaments and the aerial lineaments cannot be combined into a single class of lineaments to achieve uniform coverage of the entire CDCA and must be treated separately for statistical analysis.

From all the lineament variables which were considered for each of the four sources (LANDSAT, gravity, Skylab and aerial), 20 were selected (Table 5) for each source. Section 3.1 addresses the general approach of the selection process; Section 3.2 details the variable selection.

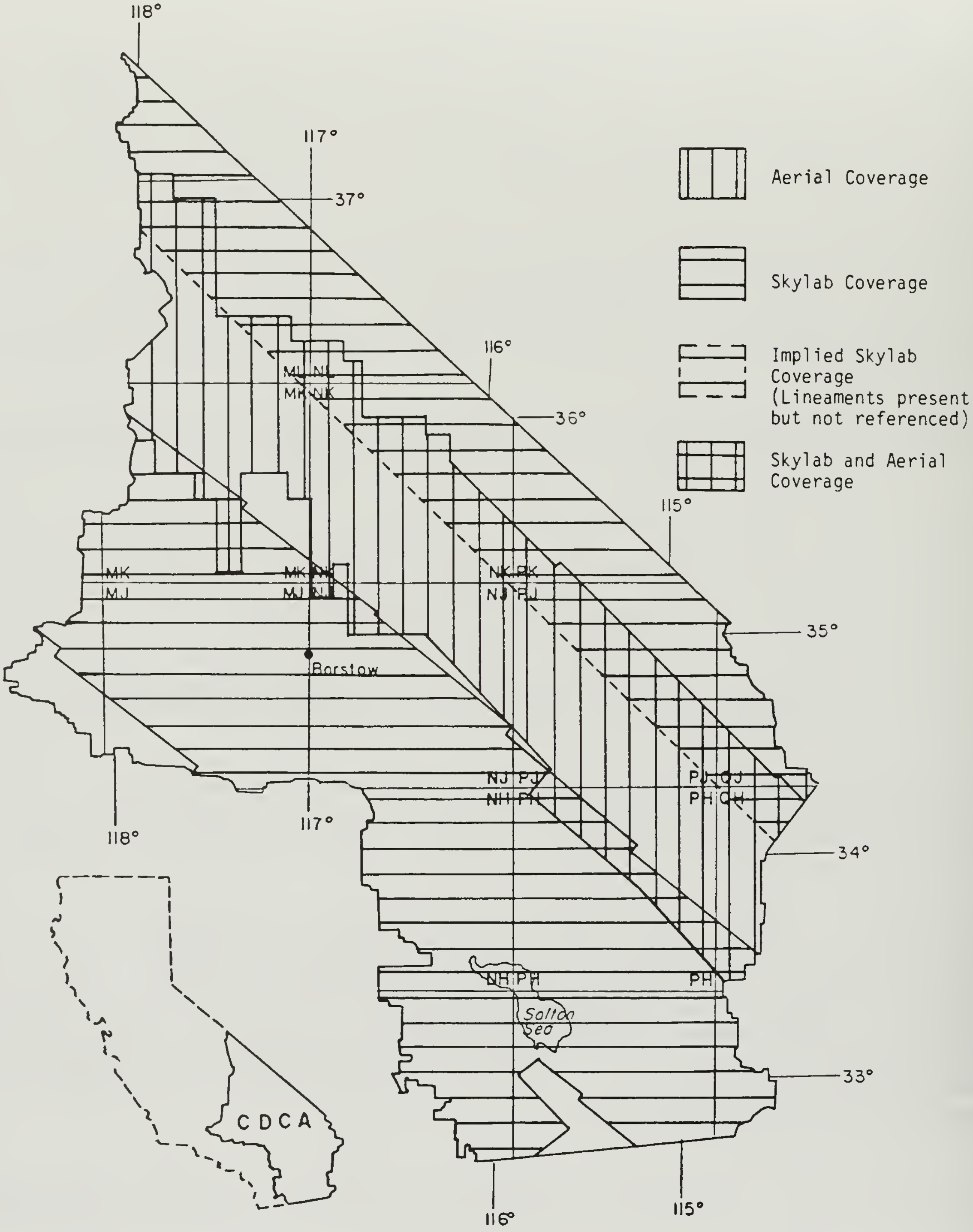


FIGURE B - I

Skylab Versus Aerial Lineament Coverage

3.1 GENERAL APPROACH FOR SELECTION OF LINEAMENT VARIABLES

Certain geological theories regarding the nature of lineaments support the use of lineament variables for resource appraisal. The main theory is that lineaments are representative of geologic structure, particularly fracture systems (Reference 91). In order to determine the statistical relationships between lineaments and mineral potential, the lineament representations (lines on a map) must be converted to a set of numbers (digitized). This quantification of lineament information should maintain, as much as possible in numeric form, the features of lineaments that are representative of mineralization. Thus, the following theories provide a framework for lineament quantification:

1. The total length of a lineament is proportional to the importance of that lineament (representative of the importance of a structural feature, Reference 93).
2. The number of lineaments represents the lineament complexity of the area. This, in turn, is representative of the structural complexity of the area (Reference 76).
3. Intersections present evidence of lineament interaction. This, in turn, is representative of structural interaction (Reference 83).
4. Certain lineament orientations (azimuths) may be correlated with mineral occurrence (References 81 and 82).

These theories indicate that the incorporation of quantified lineament information into the existing database of geological and geophysical variables may improve the scope and accuracy of the classification of mineral potential.

Several criteria constrain the selection of lineament variables. In order to be compatible with the existing data base and computation procedures, the lineaments should be represented digitally on a 2 - km by 2 - km cell basis. The variables should be reasonable in number for data manipulation and statistical significance (discussed in 3.2 below). Finally, the value of the variables should be determined from the lineament maps provided by GE (Reference 78).

The relationship between lineaments and mineral occurrence remains uncertain. Therefore, the process of lineament variable selection entails, first, the systematic itemization of likely variables, subject to the constraints above, and, second, the evaluation of the significance of each. Figure B - 2 is a flowchart of the lineament variable selection process for this study.

From the maps of lineaments, there are essentially three parameters that can be measured:

- Lineament length.
- Lineament azimuth.
- Lineament intersections.

Therefore, the list of possible lineament variables must consist of these parameters and combinations of them, which includes:

- Number of lineaments.
- Length of lineaments.
- Number of intersections.
- Length of lineaments that intersect.
- Number of lineaments with a certain orientation (a range of orientations is called an azimuth class.)
- Length of lineaments within an azimuth class.

Each of the variables involving length can be computed as length within a given cell or total length. There are other, more complicated variables that can be derived. One identifies azimuth classes (a range of lineament orientations) that are significantly correlated with mineralization and compiles variables (from the list above) involving those significant azimuth classes only (Reference 90). This method requires the prior determination of significant azimuths and is beyond the scope of this project. Another modification is to create variables that allow for the influence on a given cell of lineament parameters outside, but near, that cell. As discussed below, this was done for lineament intersections.

From this list of possible variables a set of reasonable variables (see Section 3.2.1 below) was selected. Also variables that are not supported on theoretical grounds were eliminated. This process was accomplished using inputs from an extensive literature search for theories on relationships between lineaments and mineralization and from consultation with Robert Campbell, a geologic and remote sensing Associate.

Finally, the lineament variables of Table 5 were selected by computer analysis of a test case to see which of the reasonable variables provided the most discrimination of mineral potential. The copper, lead, silver, zinc combined, or "hydrothermal" commodity category, was used for the test because of the applicability of lineament theory to hydrothermal - type mineral deposits. The geostatistical technique called D - square similarity (Appendix C of Reference 138) was used to measure the discrimination.

The details of these last two selection steps are discussed in the section below.

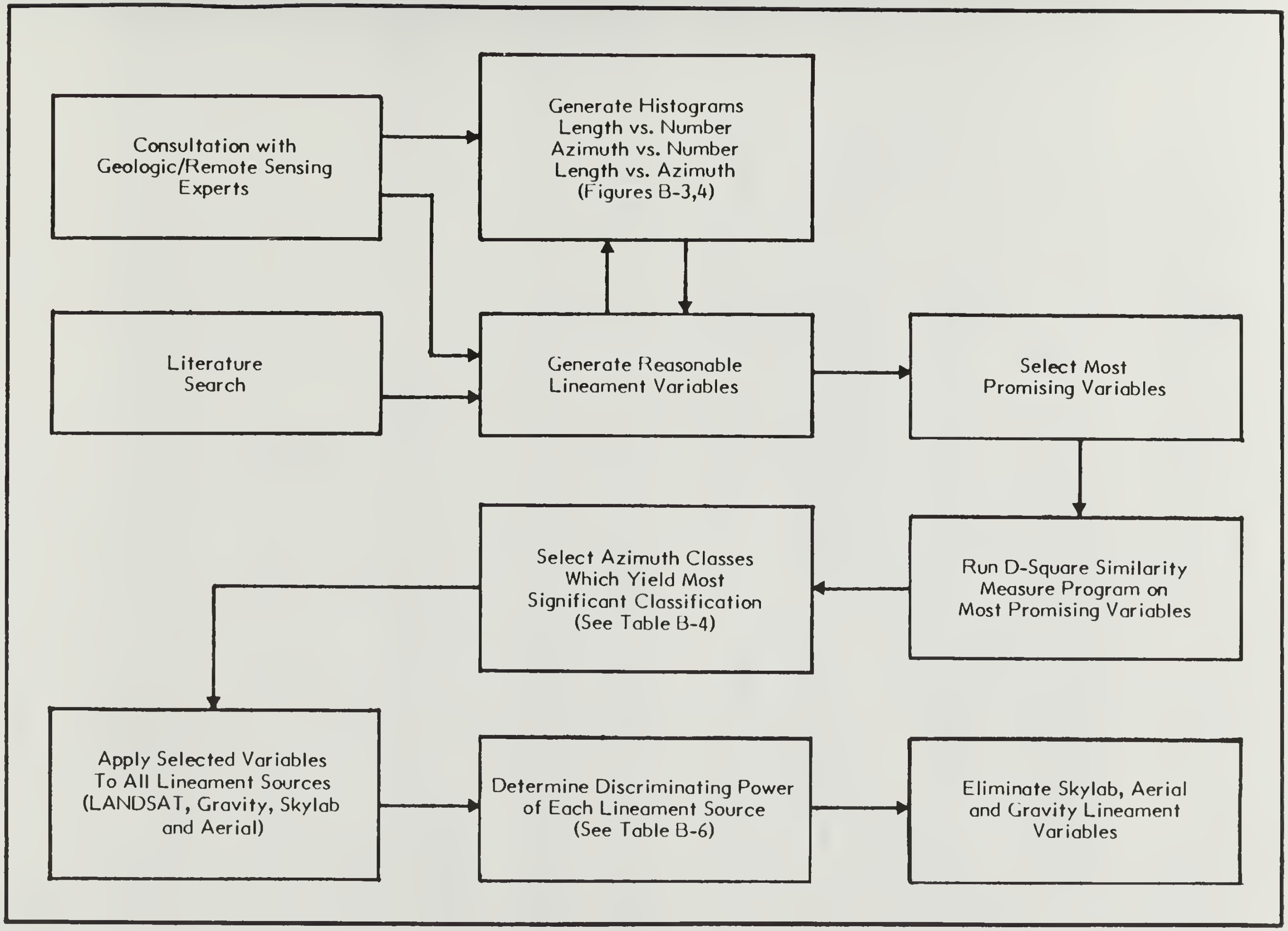


FIGURE B - 2

Flowchart Of Selection Of Lineament Variables

3.2 SELECTION OF LINEAMENT VARIABLES

3.2.1 Definition of Reasonable Variables

After the initial list of possible lineament variables was prepared, a systematic definition of reasonable variables was made based on consultation with experts and an extensive literature search. Reasonable variables are those that satisfy the criteria discussed above, namely:

- Compatible with existing data bases.
- Limited to a manageable number.
- Obtainable from the lineament maps provided.

The manageable number limitation has two components. From a practical point of view for computation, it is useful to restrict the number of variables. More importantly, to maintain statistical significance, the variables must occur frequently enough to provide discriminating power. Too fine a partition of the data, for example assigning azimuth to the nearest degree, means very low correlations between mineralization and the variables will exist, since very few cells with mineralization will have any particular variable value. For this reason, using the azimuth example again, classes of azimuths are defined. Each class is equivalent to a range of orientations.

Attributes of lineament variables that satisfy the "reasonable" criteria are discussed below.

Length

Due to the limitations of mapping lineament locations (± 1.3 km for LANDSAT) and the use of a 2 - km by 2 - km grid cell size, lineaments and intersections could be incorrectly drawn through cells adjacent to their actual location. Therefore, variable categories especially sensitive to exact location such as those involving the quantifier "length within a cell" were not considered meaningful and were eliminated.

Intersections

In order to allow for the effect lineament intersections could have on nearby cells, and to reduce the effect of location error for intersections, a rating system for weighting neighbor cells was developed (shown schematically below with each fraction representing a separate cell):

1/8	1/4	1/8
1/4	1	1/4
1/8	1/4	1/8

Each factor is proportional to the inverse of the square of the distance between cell centers. Thus, for variables involving lineament intersections, the cell value would be defined as the sum of the value in the cell plus one - fourth the sum in adjacent cells plus one - eighth the sum of values in corner cells.

Azimuth

Azimuth can take on a value between 0° and 180°. (Note lineaments with azimuths of 10° and 190° are indistinguishable because every lineament is associated with two directions, each 180° apart). Azimuth classes are uniquely defined by the number of classes and an origin. For instance, four azimuth classes implies that intervals of 45° will be the range for orientations of the same class, but the actual boundaries of the intervals is indefinite. An origin of 0° means the intervals are 0° - 45°, 45° - 90°, 90° - 135°, and 135° - 180°. On the other hand, an origin of 22.5° means the intervals are 337.5° through 360° to 22.5°, 22.5° - 67.5°, 67.5° - 112.5°, and 112.5° - 157.5°.

To aid the evaluation of azimuth groupings, several histograms were prepared:

- Number versus length (Figure B - 3).
- Number versus azimuth (Figure B - 3).
- Cumulative length versus azimuth (Figure B - 4).

Examination of the histograms (Figure B - 4) shows that LANDSAT imagery has the most sensitivity to differences in the intervals and origins of azimuth groupings. For this reason, all subsequent tests to examine the effectiveness of the various azimuth groupings were made using the LANDSAT lineament data.

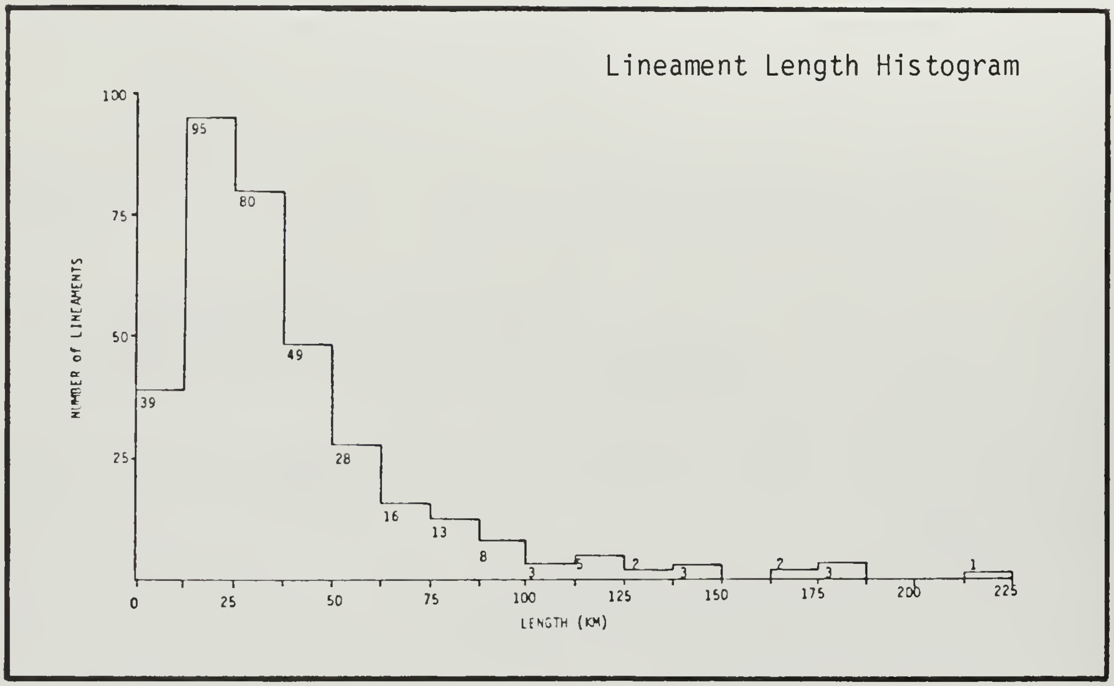
Eight azimuth groupings were selected for computer testing to provide a range of potential variables:

- Eight classes, (22 1/2°) origin at 0°.
- Eight classes, (22 1/2°) origin at 7.5°.
- Eight classes, (22 1/2°) origin at 15°.
- Six classes, (30°) origin at 0°.
- Six classes, (30°) origin at 15°.
- Four classes, (45°) origin at 0°.
- Four classes, (45°) origin at 22.5°.
- One class (i.e., no subdivision for azimuth).

3.2.2 Computer Tests of Lineament Variables

Test discrimination programs were run on the combined copper, lead, silver, zinc, or "hydrothermal" commodity category for the eight preliminary azimuth groupings and the case with no lineament variables and the results compared (Table B - 1). Although there is little, if any, significant difference among grouping schemes in the Chi - square test results, the azimuth grouping with 8 divisions and an origin of 15 degrees yielded a classification which was not bettered by any other scheme. Furthermore, this azimuth grouping offers the option of consolidation of variables to four or two divisions, and was, therefore, selected. All grouping schemes show significant discriminating power.

The last step of variable selection was performed again using the "hydrothermal" test case. The 20 selected variables for each lineament type (LANDSAT, gravity, aerial, Skylab) were used to determine the improved effectiveness of adding gravity, aerial or Skylab lineament data to LANDSAT alone. As shown in Table B - 2 gravity, Skylab and aerial lineament variables produced no significant increase in the discriminating power. The aerial and Skylab tests were made only on areas where data exist (Figure B - 1). On the basis of these results, the gravity, Skylab and aerial lineament variables were not used for further DFA analysis.



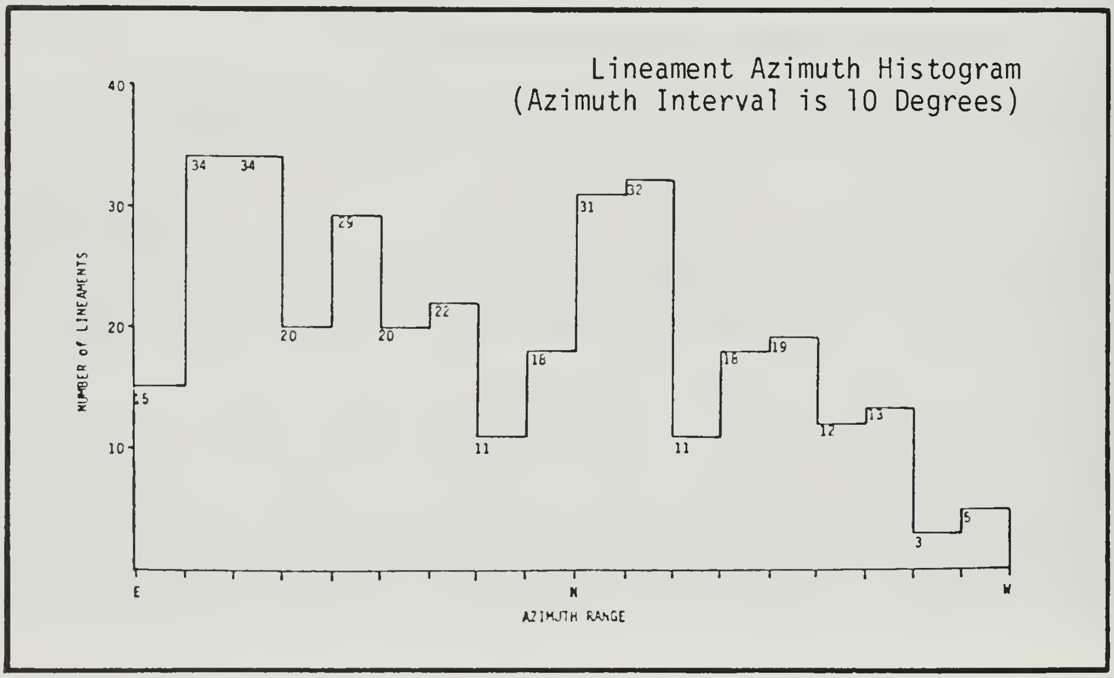
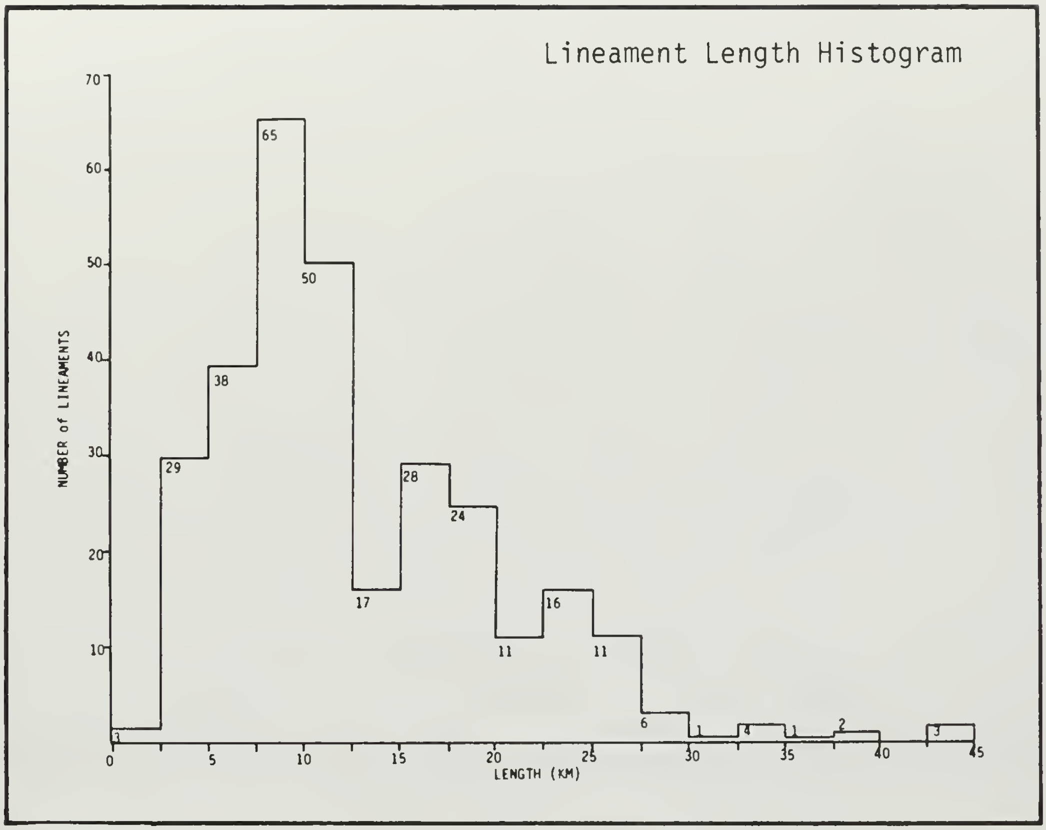


FIGURE B - 3

Lineament Length And Azimuth Histograms:
LANDSAT



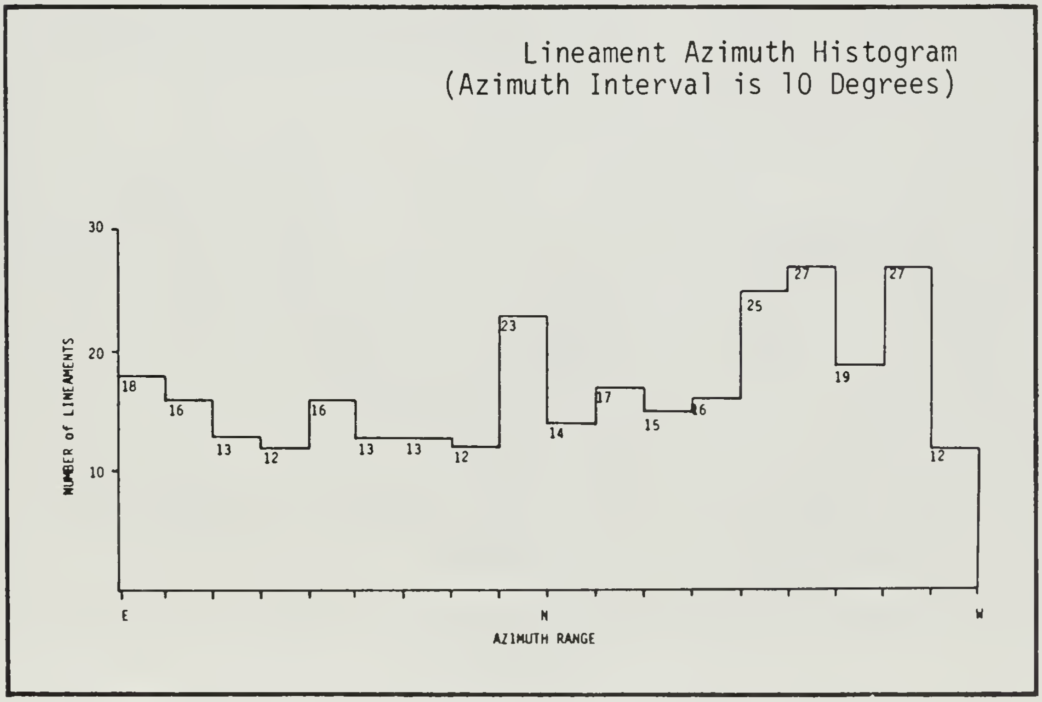
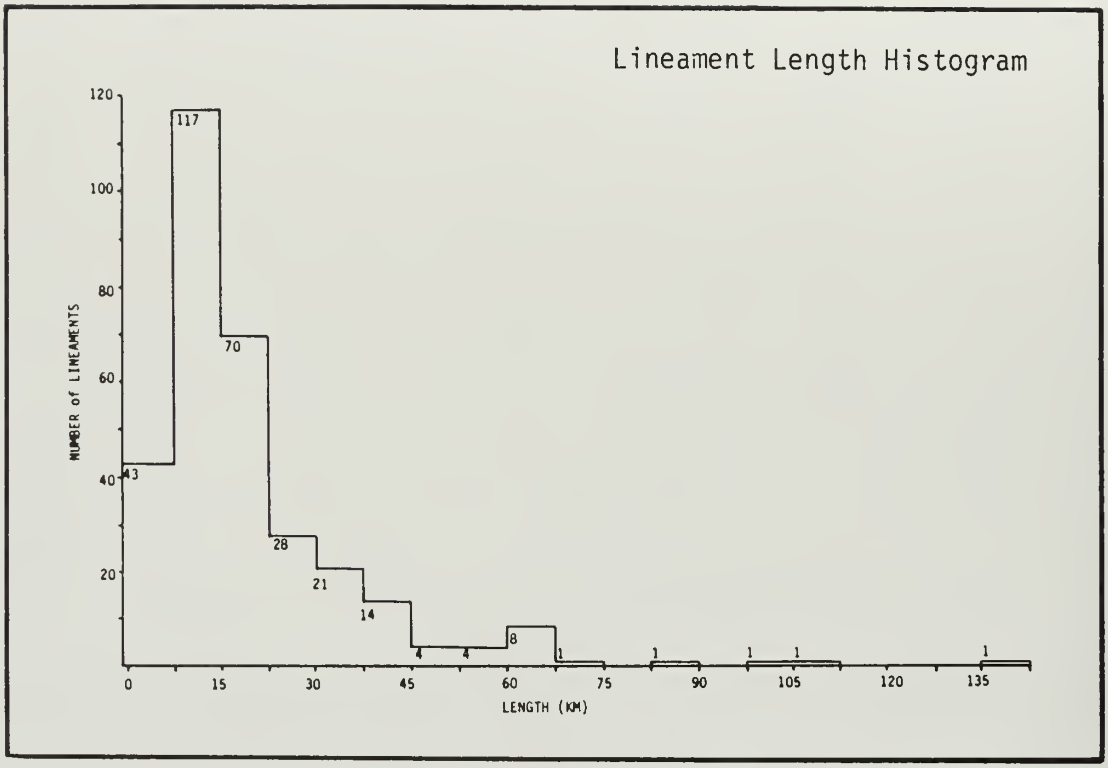


FIGURE B - 3

Lineament Length And Azimuth Histograms:
(Continued)
AERIAL



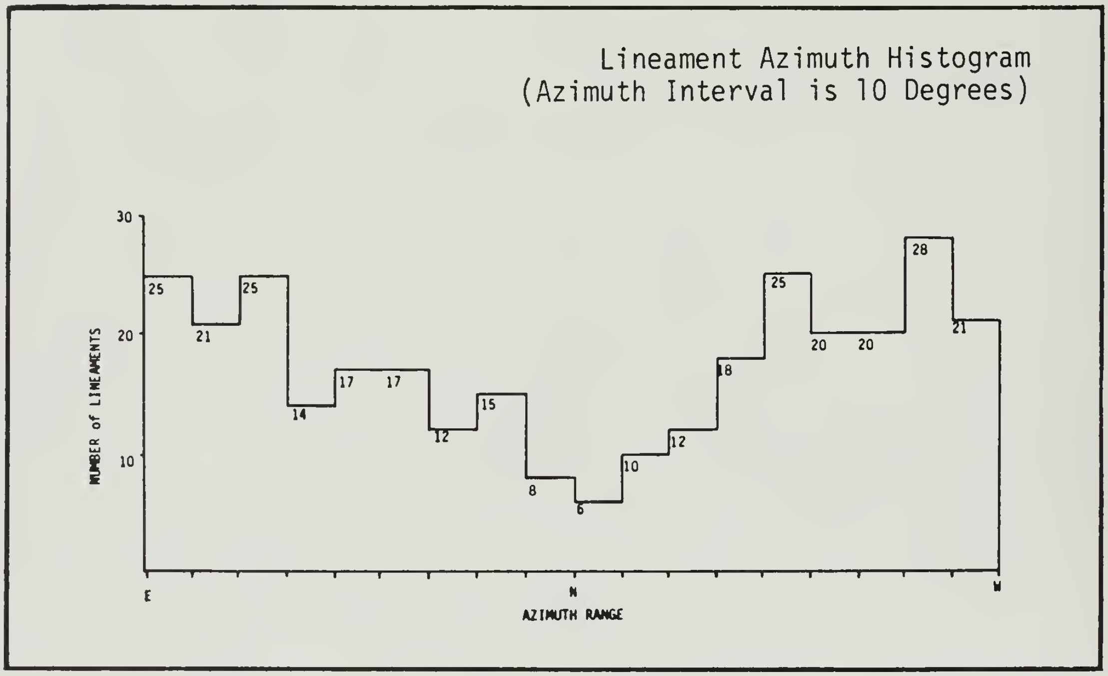
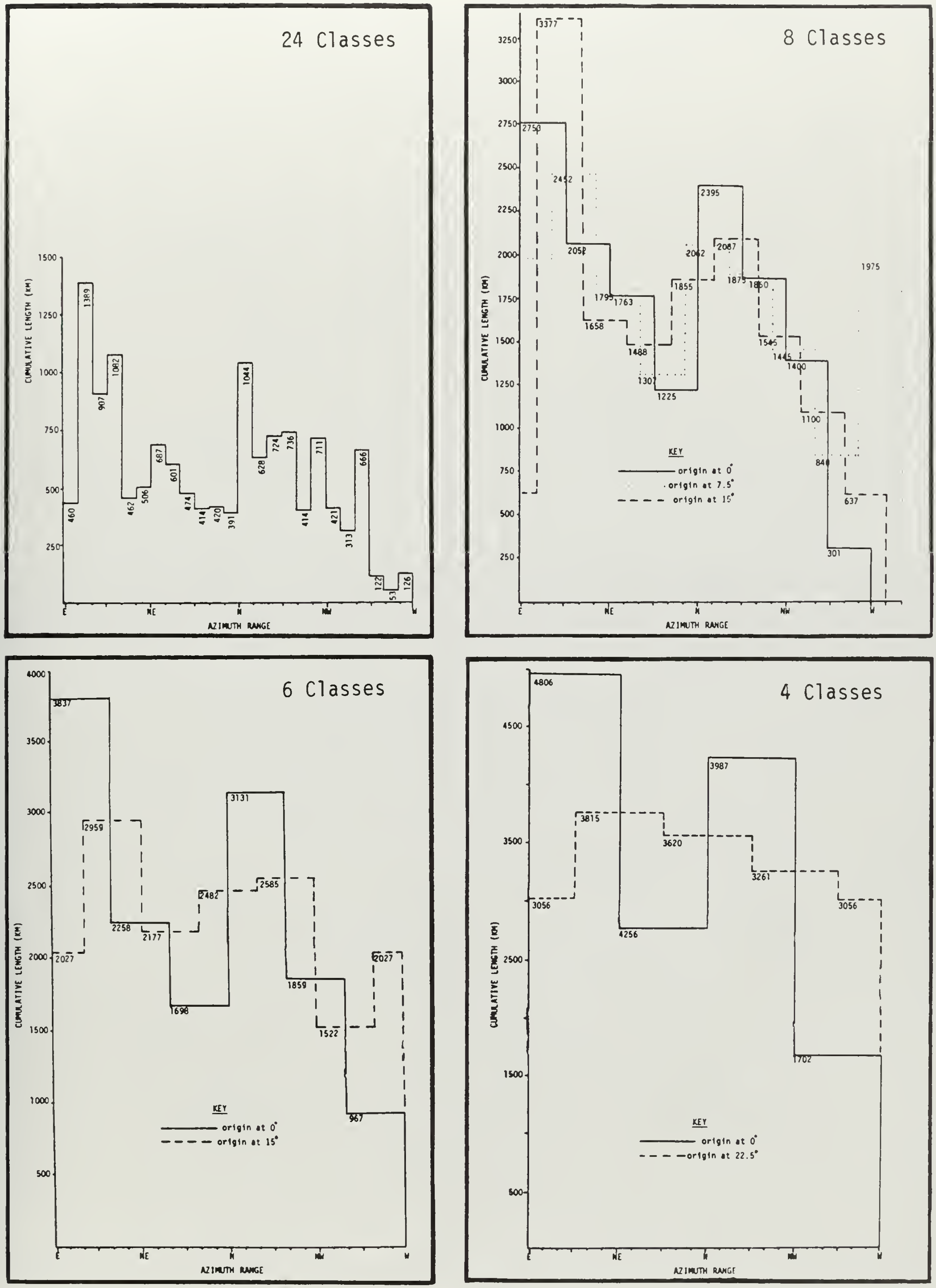


FIGURE B - 3

Lineament Length And Azimuth Histograms:
(Continued)
SKYLAB


24 Classes

8 Classes

6 Classes

4 Classes

FIGURE B-4

Cumulative Length Of Lineaments In Different Azimuth Classes: LANDSAT

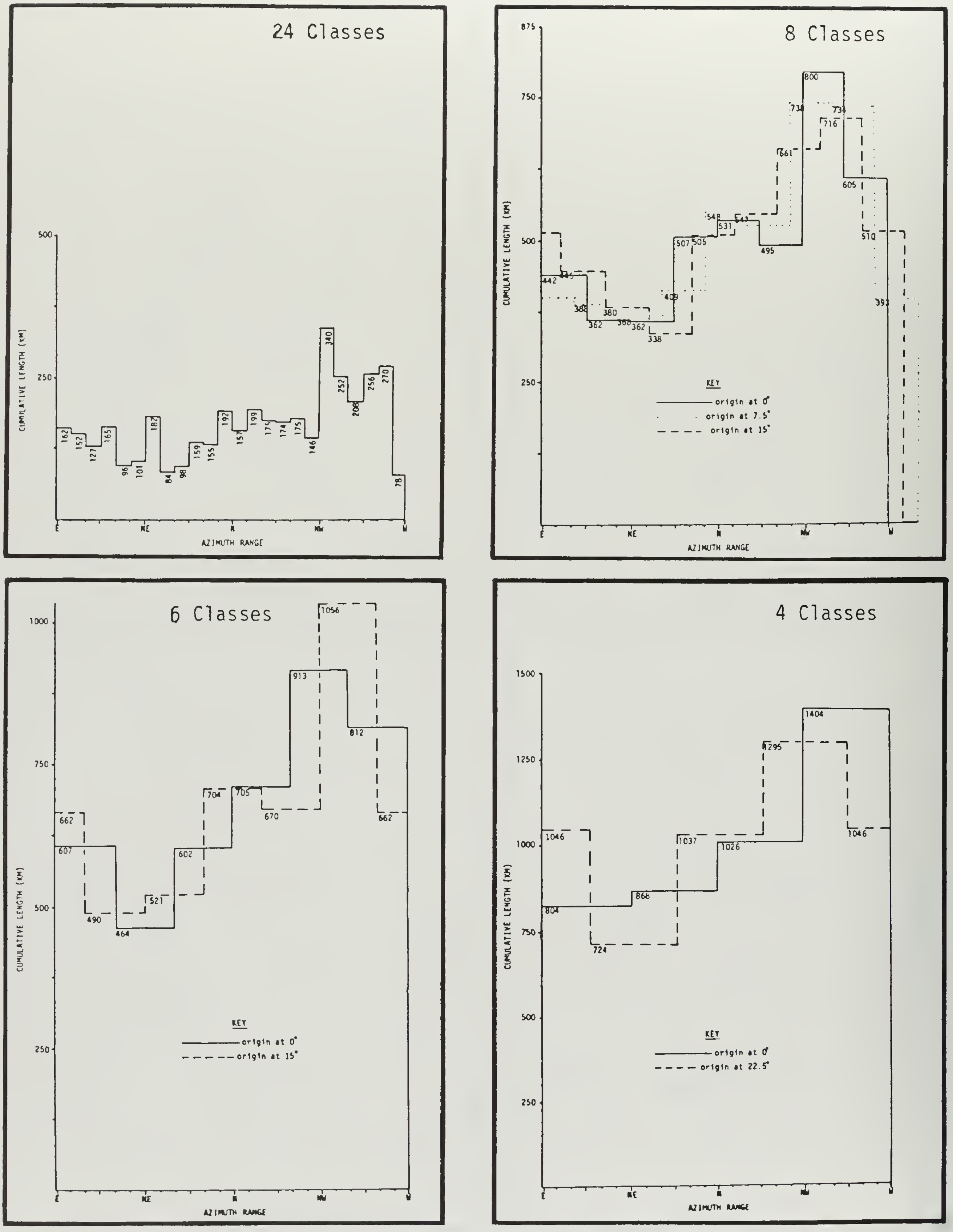


FIGURE B - 4

Cumulative Length Of Lineaments In Different Azimuth Classes:
(Contined)
AERIAL

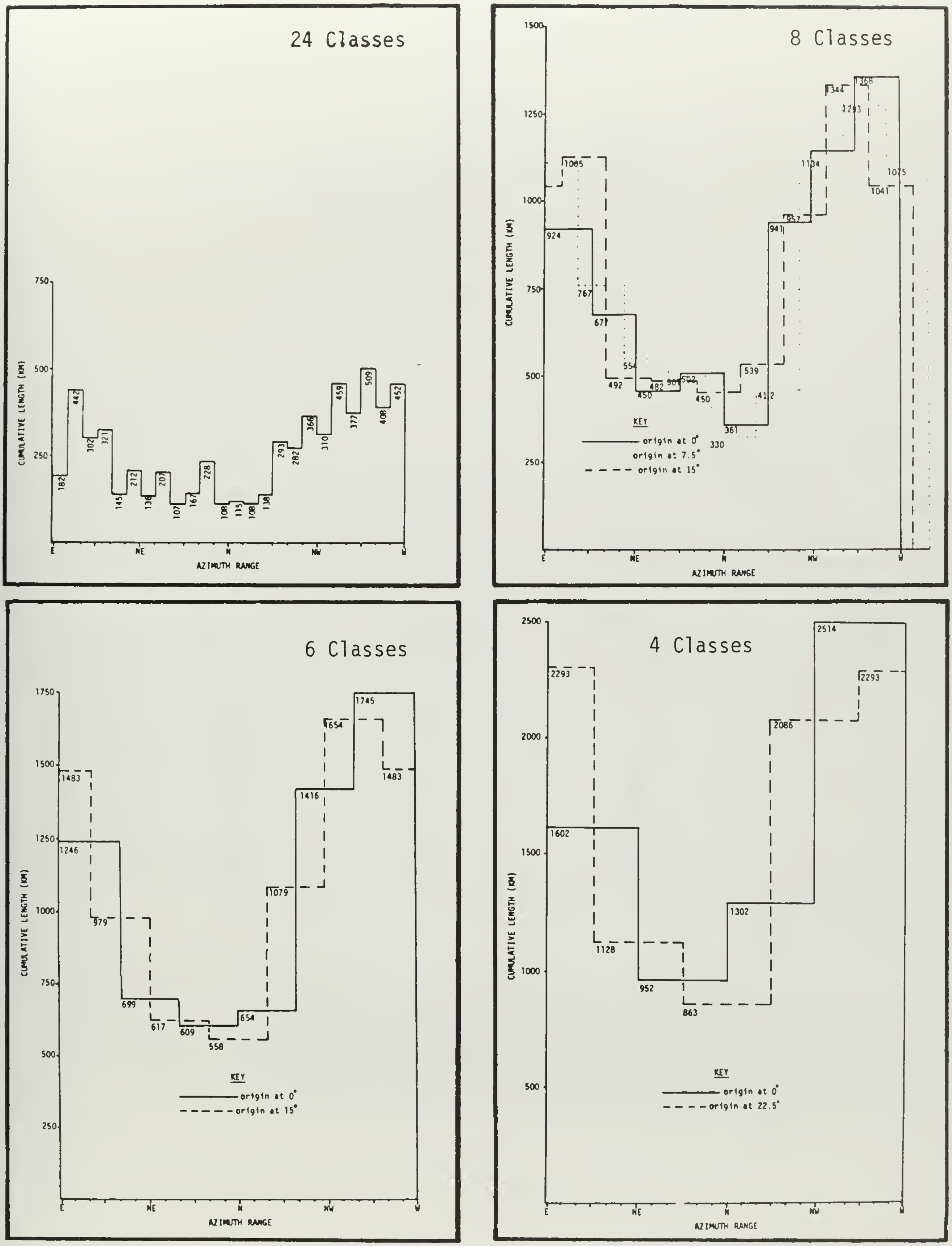


FIGURE B - 4

Cumulative Length Of Lineaments In Different Azimuth Classes:
(Continued)
SKYLAB

TABLE B - 1

Measure Of Discriminating Power Of LANDSAT Lineament Variables

Copper, Lead, Silver, Zinc Combined Case
451 Occurrences Total

			Percent			
Occurrence if a random sample[1] (chi-square)			10	25	50	75
ACTUAL OCCURRENCES PREDICTED BY D-SQUARE:						
Number of Azimuth Classes	Azimuth Class Origin (degrees)	Degrees of Freedom	Percent of Occurrences			
8	0	57	73	76	79	81
8	7.5	57	71	74	78	80
8	15	57	73	76	80	82
6	0	53	71	75	79	80
6	15	53	71	73	77	80
4	0	49	70	72	76	79
4	22.5	49	73	74	78	81
1	0	41	69	74	76	80
No lineament variables		37	72	74	77	80

---

[1] Each case should be compared to a chi - square distribution with corresponding degrees of freedom. The numbers in this row represent the expected percent of occurrences for a chi - square distribution. The more any case's percent of occurrences exceeds the chi - square distribution (Reference 95), the more significant the discriminating power of that case is.

TABLE B - 2

Measure Of Discriminating Power Of Lineament Variables By Source

		Percent			
Occurrence if a random sample[1] (chi-square)		10	25	50	75
Lineament Variables	Total Number Of Occurrence Cells	Percent of Occurrences			
LANDSAT	451	73	76	80	82
Gravity and LANDSAT	451	64	67	69	72
Aerial and LANDSAT	195	58	62	64	65
Skylab and LANDSAT	225	69	70	72	74
No lineament variable	451	72	74	77	78

---

[1] Each case should be compared to a chi - square distribution with corresponding degrees of freedom. The numbers in this row represent the expected percent of occurrences for a chi - square distribution. The more any case's percent of occurrences exceeds the chi - square distribution, the more significant the discriminating power of that case is.

4. SELECTION OF GEOCHEMICAL VARIABLES

BLM collected 2,500 samples from 1,250 locations for geochemical analysis. Two separate samples were collected at each location. One sample was separated with a - 500 micron mesh. The second sample was developed into a heavy mineral concentrate. Four subareas of the CDCA were sampled, representing about 50 percent of the area. These areas, designated as A, B, C and D, are shown in Figure B - 5. Each sample was analyzed using semi - quantitative spectrographic methods to determine concentrations of 65 elements (see Table B - 3). Fifteen elements each from the sieved samples and the heavy mineral concentrates were selected for mapping and for DFA. The selection process is discussed below.

1. Magnetic tapes containing the sampling results were obtained from USGS. The data were then placed in a computerized data base.

2. The data were screened to identify those elements with insufficient data. Many elements were not measurable at a large number of sample locations due to limitations in the measurement procedures or due to very low concentrations and, therefore, provide only very limited information. Tables B - 4 and B - 5 list elements which were not measurable at a large proportion of the sample locations. They cannot provide discriminating power in mineral potential estimates. Thus, those elements were eliminated from further analysis.

3. For the remaining elements, Product Moment Correlation Coefficients were calculated as shown in Table B - 6. (A discussion of the Pearson Product Moment Correlation Coefficient is contained in Appendix D). Tables B - 7 and B - 8 are summary lists of elements that are highly correlated with other elements for sieved samples and heavy mineral concentrates, respectively. These elements were eliminated from further analysis.

4. As a result of the recommendation of Dr. John Awald, a geochemical consultant, the following sieved sample elements were eliminated from further analysis: calcium, strontium, aluminum, germanium, gadolinium and erbium. These six elements were judged to be unimportant for discrimination. The final 30 elements are listed in Table B - 9.

5. For the remaining elements, the standard statistical measures were calculated. These measures include the mean, mode, maximum and standard deviation (see Appendix D for definitions of these terms). These statistics were calculated for each of the four sampling areas and for all sampling areas combined. The results are shown in Tables B - 10 and B - 11. As a check, these statistics were compared with those calculated by the USGS. In all cases, the results were comparable.

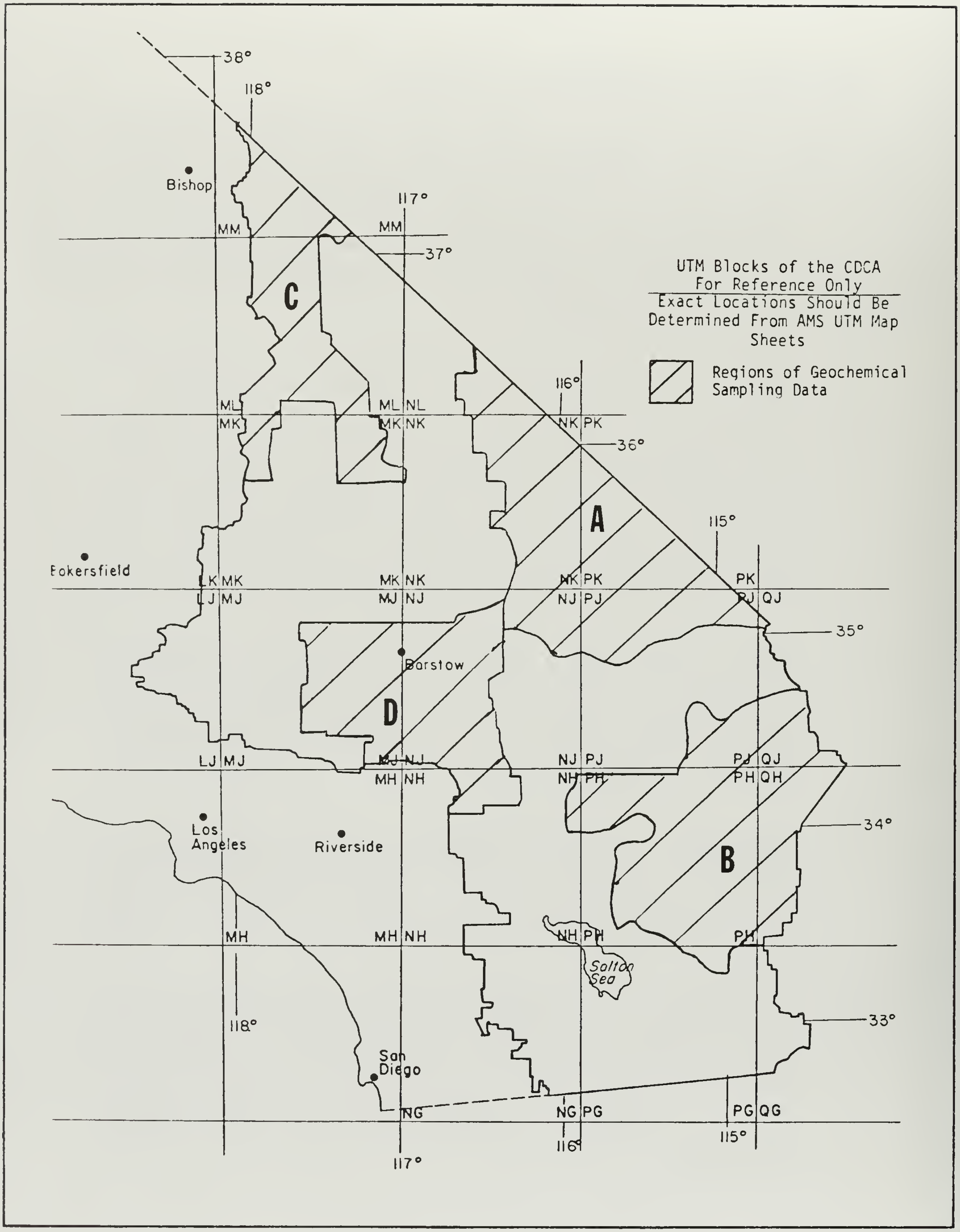


FIGURE B-5

Map Of CDCA Showing Regions Of Geochemical Sampling

TABLE B - 3

Geochemical Sampling Data: Elements

Number	Element	Symbol	Units*
1	Iron	Fe	percent
2	Magnesium	Mg	percent
3	Calcium	Ca	percent
4	Titanium	Ti	percent
5	Manganese	Mn	ppm
6	Silver	Ag	ppm
7	Arsenic	As	ppm
8	Gold	Au	ppm
9	Boron	B	ppm
10	Barium	Ba	ppm
11	Beryllium	Be	ppm
12	Bismuth	Bi	ppm
13	Cadmium	Cd	ppm
14	Colbalt	Co	ppm
15	Chromium	Cr	ppm
16	Copper	Cu	ppm
17	Lanthanum	La	ppm
18	Molybdenum	Mo	ppm
19	Niobium	Nb	ppm
20	Nickel	Ni	ppm
21	Lead	Pb	ppm
22	Palladium	Pd	ppm
23	Platinum	Pt	ppm
24	Antimony	Sb	ppm
25	Scandium	Sc	ppm
26	Tin	Sn	ppm
27	Strontium	Sr	ppm
28	Technetium	Tc	ppm
29	Uranium	U	ppm
30	Vanadium	V	ppm
31	Tungsten	W	ppm
32	Yttrium	Y	ppm
33	Zinc	Zn	ppm
34	Zirconium	Zr	ppm
35	Silicon	Si	percent
36	Aluminum	Al	percent
37	Sodium	Na	percent
38	Potassium	K	percent
39	Phosphorus	P	percent
40	Cerium	Ce	ppm
41	Gallium	Ga	ppm
42	Germanium	Ge	ppm
43	Hafnium	Hf	ppm
44	Indium	In	ppm
45	Lithium	Li	ppm
46	Rhenium	Re	ppm
47	Tantalum	Ta	ppm
48	Thorium	Th	ppm
49	Thallium	Tl	ppm
50	Ytterbium	Yb	ppm
51	Praseodymium	Pr	ppm
52	Neodymium	Nd	ppm
53	Samarium	Sm	ppm
54	Europium	Eu	ppm
55	Gadolinium	Gd	ppm
56	Terbium	Tb	ppm
57	Dysoprosium	Dy	ppm
58	Holmium	Ho	ppm
59	Erbium	Er	ppm
60	Thulium	Tm	ppm
61	Lutetium	Lu	ppm
62	Iridium	Ir	ppm
63	Osmium	Os	ppm
64	Rhodium	Rh	ppm
65	Ruthenium	Ru	ppm

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*ppm = parts per million

TABLE B - 4

Geochemical Sampling Data: Low Frequency Elements

Sieved Samples

Element		Not Measurable (Number of Samples)	No Reading (Number of Samples)	Combined Percent of Total*
Number	Symbol			
6	Ag	1094	9	89
7	As	1200	9	97
8	Au	1202	9	97
12	Bi	1199	9	97
13	Cd	1182	9	96
22	Pd	1209	9	97
23	Pt	1199	9	97
24	Sb	1200	9	97
26	Sn	1164	9	94
28	Tc		1243	100
29	U	1198	9	97
31	W	1198	9	97
39	P	1202	9	97
43	Hf	1171	9	95
44	In	1234	9	100
45	Li	1192	9	96
46	Re	1206	9	97
47	Ta	1234	9	100
48	Th	1158	9	94
49	Tl	1113	18	91
51	Pr	1076	11	87
53	Sm	1145	9	93
56	Tb	1166	9	94
57	Dy	1229	9	100
58	Ho	1075	9	87
60	Tm	1197	9	98
61	Lu	1234	9	100
62	Ir	1230	9	100
63	Os	1234	9	100
64	Rh	1234	9	100
65	Ru	1198	9	97

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* 1243 Total Samples

TABLE B - 5

Geochemical Sampling Data: Low Frequency Elements

Heavy Mineral Concentrate Samples

Element		Not Measurable (Number of Samples)	No Reading (Number of Samples)	Combined Percent of Total*
Number	Symbol			
7	As	1235	4	100
8	Au	1231	4	99
12	Bi	1161	3	94
13	Cd	1020	3	82
22	Pd	1239	3	100
23	Pt	1186	3	96
24	Sb	1237	3	100
28	Tc		1243	100
29	U	1195	3	96
31	W	1200	3	97
35	Si		1242	100
37	Na		1242	100
39	P	1215	3	98
44	In	1239	3	100
45	Li	1040	3	84
46	Re	1239	3	100
47	Ta	1236	3	100
48	Th	1157	3	93
49	Tl	1038	3	84
56	Tb	1087	4	88
57	Dy	1098	4	89
58	Ho	1117	4	90
60	Tm	1142	4	92
61	Lu	1164	3	94
62	Ir	1213	3	98
63	Os	1239	3	100
64	Rh	1239	3	100
65	Ru	1236	3	100

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*1243 Total Samples

TABLE B - 6

Geochemical Sampling Data:
Pearson Product Moment Correlation Coefficients

Sieved Samples

	Mg V2	Ca V3	Ti V4	Mn V5	B V9	Ba V10	Be V11	Co V14	Cr V15	Cu V16	La V17	Mo V18	Nb V19	Ni V20	Pb V21	Sc V25	Sr V27	V V30	Y V32	Zn V33	Zr V34	Si V35	Al V36	Na V37	K V38	Ce V40	Ga V41	Ge V42	Yb V50	Nd V52	Eu V54	Gd V55	Er V59	
Fe V1	0.05	-0.15	0.63	0.58	0.39	-0.02	0.16	0.29	0.44	0.17	0.60	0.83	0.48	0.17	0.13	0.23	-0.16	0.83	0.61	0.18	0.52	-0.17	-0.12	-0.07	-0.24	0.70	0.64	0.08	0.56	0.14	0.57	0.16	0.28	V1 Fe
Mg V2		0.46	0.32	0.14	0.09	-0.06	-0.02	0.16	0.29	0.10	-0.02	0.05	0.04	0.36	-0.02	0.27	0.01	0.05	0.02	0.11	0.12	-0.33	-0.18	-0.16	-0.29	0.02	-0.11	-0.06	0.02	0.02	0.08	-0.05	0.01	V2 Mg
Ca V3			-0.12	-0.07	0.09	-0.02	-0.16	-0.02	0.04	0.01	-0.07	-0.06	-0.12	0.07	-0.03	0.04	0.22	-0.12	-0.12	0.07	-0.09	-0.34	-0.25	-0.18	-0.24	-0.07	-0.23	-0.09	-0.14	0.04	-0.02	-0.15	0.04	V3 Ca
Ti V4				0.57	0.20	0.09	0.36	0.16	0.47	0.02	0.48	0.42	0.44	0.33	0.05	0.53	0.04	0.64	0.60	0.10	0.49	0.06	0.20	0.13	-0.02	0.50	0.50	0.15	0.46	0.14	0.52	0.14	0.18	V4 Ti
Mn V5					0.25	0.37	0.19	0.14	0.36	0.10	0.41	0.49	0.61	0.21	0.14	0.39	-0.08	0.49	0.56	0.19	0.48	-0.06	0.03	0.04	0.03	0.48	0.42	0.09	0.49	0.21	0.17	0.18	0.25	V5 Mn
B V9						0.11	-0.01	0.16	0.23	0.12	0.20	0.41	0.15	0.15	0.10	0.05	0.02	0.32	0.17	0.13	0.19	-0.07	-0.10	-0.09	-0.06	0.26	0.17	0.08	0.13	0.07	0.21	0.07	0.06	V9 B
Ba V10							0.02	0.01	0.06	0.02	0.05	-0.08	0.00	0.08	0.10	0.11	0.21	0.00	0.01	0.00	0.12	0.19	0.26	0.17	0.47	0.02	0.13	0.09	0.02	0.05	0.10	0.09	-0.02	V10 Ba
Be V11								0.03	0.15	0.00	0.22	0.05	0.18	0.16	0.03	0.29	0.14	0.04	0.28	0.03	0.13	0.17	0.30	0.26	0.10	0.10	0.21	0.07	0.22	0.03	0.22	0.02	0.11	V11 Be
Co V14									0.20	0.83	0.06	0.12	0.04	0.19	0.02	0.18	-0.01	0.15	0.08	0.06	0.06	-0.08	-0.02	-0.04	-0.09	0.09	0.14	0.01	0.07	0.04	0.14	0.00	0.01	V14 Co
Cr V15										0.04	0.23	0.13	0.14	0.76	0.06	0.51	0.04	0.43	0.24	0.09	0.21	-0.12	0.06	-0.04	-0.20	0.30	0.24	0.04	0.19	0.33	0.28	0.01	0.14	V15 Cr
Cu V16											0.01	0.07	0.00	0.04	0.15	0.04	-0.05	0.05	0.02	0.48	0.01	-0.07	-0.07	-0.05	-0.06	0.03	0.05	0.01	0.01	0.00	0.06	-0.01	0.00	V16 Cu
La V17												0.47	0.44	0.09	0.09	0.18	-0.06	0.39	0.68	0.12	0.36	-0.06	0.00	0.04	-0.09	0.83	0.53	0.07	0.55	0.58	0.59	0.08	0.37	V17 La
Mo V18													0.41	0.08	0.23	0.08	-0.19	0.71	0.49	0.21	0.43	-0.23	-0.27	-0.14	-0.28	0.63	0.48	0.00	0.45	0.11	0.45	0.12	0.34	V18 Mo
Nb V19														-0.01	0.06	0.12	-0.15	0.36	0.62	0.11	0.56	-0.02	-0.03	0.06	-0.01	0.47	0.32	0.07	0.55	0.12	0.35	0.16	0.32	V19 Nb
Ni V20															0.02	0.50	0.15	0.15	0.06	0.04	0.06	-0.07	0.14	0.02	-0.10	0.11	0.08	0.04	0.02	0.11	0.15	-0.03	0.02	V20 Ni
Pb V21																0.00	-0.06	0.07	0.06	0.35	0.06	0.04	-0.02	0.01	0.05	0.10	0.06	0.05	0.07	0.08	0.06	0.01	0.17	V21 Pb
Sc V25																	0.13	0.22	0.32	0.05	0.23	0.01	0.13	0.06	0.03	0.17	0.24	0.10	0.21	0.09	0.31	0.03	0.06	V25 Sc
Sr V27																		-0.08	-0.18	-0.07	-0.14	0.11	0.44	0.40	0.21	-0.10	0.14	-0.04	-0.20	0.02	0.15	0.01	-0.02	V27 Sr
V V30																			0.44	0.13	0.44	-0.13	-0.08	-0.02	-0.18	0.55	0.54	0.04	0.42	0.09	0.50	0.17	0.22	V30 V
Y V32																				0.13	0.54	-0.01	0.00	0.03	-0.07	0.62	0.45	0.12	0.82	0.26	0.55	0.10	0.44	V32 Y
Zn V33																					0.10	-0.10	-0.10	-0.05	-0.09	0.15	0.07	-0.01	0.11	0.05	0.11	0.00	0.08	V33 Zn
Zr V34																						-0.04	-0.01	0.02	0.00	0.42	0.34	0.09	0.57	0.08	0.38	0.22	0.28	V34 Zr
Si V35																							0.60	0.59	0.46	-0.17	0.18	0.22	-0.03	-0.03	-0.11	0.19	-0.12	V35 Si
Al V36																								0.63	0.55	-0.13	0.39	0.30	-0.02	0.01	0.08	0.18	-0.07	V36 Al
Na V37																									0.43	-0.05	0.42	0.14	0.02	0.02	0.07	0.18	-0.01	V37 Na
K V38																										-0.14	0.18	0.19	-0.07	-0.01	-0.04	0.12	0.00	V38 K
Ce V40																											0.55	0.04	0.52	0.53	0.56	0.12	0.35	V40 Ce
Ga V41																												0.22	0.40	0.21	0.47	0.30	0.20	V41 Ga
Ge V42																													0.08	0.03	0.06	0.14	0.04	V42 Ge
Yb V50																														0.17	0.50	0.13	0.42	V50 Yb
Nd V52																															0.22	0.03	0.19	V52 Nd
Eu V54																																0.06	0.29	V54 Eu
Gd V55																																	0.07	V55 Gd

Heavy Mineral Concentrate Samples

	Mg V2	Ca V3	Ti V4	Mn V5	Ag V6	B V9	Ba V10	Be V11	Co V14	Cr V15	Cu V16	La V17	Mo V18	Nb V19	Ni V20	Pb V21	Sc V25	Sn V26	Sr V27	V V30	Y V32	Zn V33	Zr V34	Al V36	K V38	Ce V40	Ga V41	Ge V42	Hf V43	Yb V50	Pr V51	Nd V52	Sm V53	Eu V54	Gd V55	Er V59	
Fe V1	0.03	-0.05	0.70	0.66	0.10	0.57	0.00	0.03	0.34	0.39	0.16	0.59	0.58	0.50	0.09	0.09	0.60	0.29	-0.05	0.88	0.54	0.40	0.63	0.03	-0.22	0.54	0.72	0.38	0.59	0.53	0.37	0.44	0.38	0.42	0.46	0.19	V1 Fe
Mg V2		0.61	0.09	0.05	0.00	-0.03	-0.09	-0.05	0.13	0.38	0.02	-0.02	0.01	0.06	0.48	-0.02	0.15	0.03	-0.01	0.11	-0.05	0.07	0.08	-0.12	-0.21	0.01	-0.06	0.04	0.11	-0.01	0.01	-0.01	-0.01	-0.03	0.03	-0.01	V2 Mg
Ca V3			-0.05	-0.06	-0.01	-0.04	-0.04	-0.01	0.01	-0.01	0.00	-0.05	-0.01	-0.03	0.01	0.00	-0.03	0.01	-0.01	0.05	-0.04	0.02	-0.03	-0.05	-0.04	-0.03	-0.04	-0.00	-0.03	-0.04	-0.02	-0.04	-0.02	-0.03	-0.02	0.00	V3 Ca
Ti V4				0.69	0.16	0.29	-0.05	0.07	0.22	0.19	0.09	0.58	0.35	0.76	0.03	0.03	0.56	0.31	-0.03	0.75	0.47	0.35	0.72	0.12	-0.10	0.53	0.48	0.46	0.62	0.55	0.33	0.45	0.35	0.51	0.56	0.15	V4 Ti
Mn V5					0.14	0.31	0.01	0.06	0.16	0.21	0.13	0.55	0.36	0.65	0.02	0.10	0.58	0.34	-0.01	0.61	0.51	0.38	0.54	0.11	-0.12	0.49	0.47	0.50	0.48	0.64	0.33	0.44	0.35	0.40	0.42	0.16	V5 Mn
Ag V6						0.06	0.17	0.02	0.02	-0.01	0.17	0.10	0.13	0.18	-0.03	0.22	0.10	0.08	0.34	0.10	0.02	0.34	0.13	-0.09	-0.04	0.12	0.00	0.21	0.10	0.15	0.07	0.07	0.06	0.05	0.12	0.05	V6 Ag
B V9							0.07	0.02	0.16	0.23	0.10	0.18	0.46	0.17	0.07	0.11	0.22	0.12	0.03	0.49	0.15	0.25	0.29	-0.03	-0.10	0.20	0.39	0.19	0.30	0.19	0.15	0.14	0.13	0.10	0.21	0.09	V9 B
Ba V10								0.00	0.00	0.04	0.01	-0.04	-0.02	-0.09	0.01	0.09	-0.03	-0.04	0.46	-0.02	-0.03	0.02	-0.06	0.06	0.17	-0.02	0.03	-0.04	-0.06	-0.07	-0.01	-0.01	-0.04	-0.03	-0.02	-0.03	V10 Ba
Be V11									0.00	0.00	0.01	0.08	0.03	0.11	0.03	0.00	0.04	0.04	0.02	0.07	0.03	0.01	0.07	0.16	0.17	0.11	0.13	0.10	0.06	0.10	0.11	0.09	0.09	0.09	0.09	0.07	V11 Be
Co V14										0.20	0.57	0.14	0.21	0.10	0.23	0.02	0.25	0.06	0.02	0.24	0.13	0.11	0.17	0.05	-0.10	0.12	0.25	0.06	0.17	0.11	0.08	0.08	0.10	0.11	0.13	0.05	V14 Co
Cr V15											0.04	0.30	0.20	0.05	0.74	0.05	0.37	0.05	0.04	0.32	0.12	0.13	0.15	0.07	-0.17	0.12	0.26	0.08	0.17	0.09	0.10	0.08	0.07	0.05	0.13	0.03	V15 Cr
Cu V16												0.05	0.14	0.08	0.01	0.17	0.08	0.06	0.01	0.09	0.04	0.58	0.06	-0.06	-0.06	0.07	0.11	0.10	0.06	0.08	0.05	0.05	0.05	0.04	0.07	0.02	V16 Cu
La V17													0.28	0.60	-0.04	0.04	0.52	0.29	0.00	0.59	0.70	0.27	0.59	0.12	-0.11	0.82	0.47	0.34	0.50	0.66	0.59	0.81	0.64	0.70	0.46	0.20	V17 La
Mo V18														0.26	0.04	0.29	0.26	0.19	-0.04	0.53	0.22	0.35	0.31	-0.10	-0.14	0.29	0.42	0.28	0.31	0.26	0.18	0.22	0.19	0.17	0.23	0.08	V18 Mo
Nb V19															-0.06	0.04	0.41	0.36	-0.02	0.57	0.48	0.32	0.68	0.07	-0.07	0.52	0.33	0.45	0.57	0.62	0.34	0.47	0.33	0.51	0.48	0.18	V19 Nb
Ni V20																0.00	0.17	-0.02	0.05	0.06	-0.04	0.02	0.00	0.10	-0.12	-0.01	0.04	-0.02	0.02	-0.04	0.01	-0.03	-0.01	-0.02	0.01	0.00	V20 Ni
Pb V21																	0.04	0.07	0.10	0.07	0.03	0.36	0.02	-0.01	0.04	0.05	0.06	0.04	0.03	0.05	0.04	0.02	0.03	0.03	0.02	0.03	V21 Pb
Sc V25																		0.21	0.02	0.53	0.51	0.26	0.46	0.35	-0.16	0.47	0.49	0.30	0.41	0.47	0.32	0.43	0.33	0.38	0.34	0.14	V25 Sc
Sn V26																			-0.03	0.31	0.24	0.19	0.27	0.01	-0.06	0.24	0.24	0.29	0.26	0.32	0.15	0.21	0.17	0.23	0.22	0.10	V26 Sn
Sr V27																				0.00	0.01	-0.03	-0.01	0.16	0.16	0.05	0.08	-0.02	0.00	-0.04	0.05	0.04	0.02	0.08	-0.01	-0.01	V27 Sr
V V30																					0.51	0.36	0.67	0.06	-0.16	0.55	0.68	0.39	0.63	0.51	0.38	0.45	0.39	0.52	0.46	0.16	V30 V
Y V32																						0.23	0.51	0.14	-0.13	0.53	0.41	0.18	0.47	0.55	0.34	0.53	0.41	0.51	0.32	0.14	V32 Y
Zn V33																							0.29	-0.08	-0.14	0.25	0.26	0.26	0.28	0.29	0.15	0.20	0.17	0.17	0.21	0.07	V33 Zn
Zr V34																								0.01	-0.16	0.49	0.38	0.27	0.86	0.54	0.32	0.40	0.33	0.53	0.50	0.17	V34 Zr
Al V36																									0.51	0.08	0.37	-0.01	-0.02	0.06	0.05	0.11	0.06	0.16	0.00	0.03	V36 Al
K V38																										-0.02	0.14	-0.01	-0.16	-0.07	0104	-0.01	0.01	-0.01	-0.06	0.05	V38 K
Ce V40																											0.47	0.55	0.43	0.71	0.90	0.82	0.84	0.79	0.60	0.51	V40 Ce
Ga V41																												0.30	0.17	0.41	0.36	0.42	0.36	0.42	0.34	0.21	V41 Ga
Ge V42																													0.22	0.52	0.54	0.41	0.44	0.37	0.46	0.35	V42 Ge
Hf V43																														0.48	0.29	0.34	0.33	0.46	0.44	0.16	V43 Hf
Yb V50																															0.61	0.62	0.63	0.67	0.57	0.54	V50 Yb
Pr V51																																0.68	0.85	0.76	0.55	0.71	V51 Pr
Nd V52																																	0.75	0.69	0.46	0.22	V52 Nd
Sm V53																																		0.76	0.51	0.48	V53 Sm
Eu V54																																			0.50	0.48	V54 Eu
Gd V55																																				0.42	V55 Gd

TABLE B - 7

Geochemical Sampling Data: Highly Correlated Elements

Sieved Samples

Element		Correlated Variables (Correlation Coefficient)
Number	Symbol	
1	Fe	Mo(.83), V(.83)
17	La	Ti(.48), Mn(.43), Mo(.47)
20	Ni	Cr(.76)
25	Sc	Ti(.53), Cr(.51), Al(.33)
32	Y	Mn(.56), Ti(.60), Ce(.62), Nb(.62)
34	Zr	Mn(.48), Ti(.50), Nb(.56)
35	Si	Al(.60), Ca(.34), Mg(.33)
37	Na	Al(.63), Sr(.40)
38	K	Al(.55), Ba(.47)
41	Ga	Ti(.50), V(.54), Ce(.55)
50	Yb	Mn(.49), Nb(.55), Ce(.52)
52	Nd	Ce(.53)
54	Eu	Ti(.52), V(.50), Ce(.56)

TABLE B-8

Geochemical Sampling Data: Highly Correlated Elements

Heavy Mineral Concentrates

Element		Correlated Variables (Correlation Coefficient)
Number	Symbol	
1	Fe	Ti(.70), Mn(.66)
3	Ca	Mg(.61)
9	B	Mo(.46)
17	La	Ce(.82)
19	Nb	Ti(.76), Mn(.65)
20	Ni	Cr(.74)
25	Sc	Mn(.58), Ti(.56), Ce(.47)
27	Sr	Ba(.46)
30	V	Ti(.75), Mn(.61)
32	Y	Mn(.51), Ti(.47), Ce(.53)
34	Zr	Ti(.72), Mn(.54)
36	Al	K(.51)
41	Ga	Mn(.47), Ti(.48), Ce(.47)
42	Ge	Ce(.55), Ti(.46), Mn(.50)
43	Hf	Ti(.62), Mn(.48)
50	Yb	Mn(.64), Ti(.55), Ce(.71)
51	Pr	Ce(.90)
52	Nd	Ce(.82)
53	Sm	Ce(.84)
54	Eu	Ti(.51), Ce(.79)
55	Gd	Ti(.56), Ce(.60)
59	Er	Ce(.51)

TABLE B - 9

Geochemical Sampling Data: Elements Selected For Contouring And DFA

Sieved Samples	Heavy Mineral Concentrates
Mg	Mg
Ti	Ti
Mn	Mn
B	Ag
Ba	Ba
Be	Be
Co	Co
Cr	Cr
Cu	Cu
Mo	Mo
Nb	Pb
Pb	Sn
V	Zn
Zn	K
Ce	Ce

TABLE B - 10

Geochemical Sampling Data: Basic Statistics For Selected Elements

Sieved Samples

Element (units)	Sampling Area (see fig. B5)	Mode	Mean	Maximum Sample Value	Standard Deviation
Magnesium (percent)	All	1.2	1.4	13.0	1.1
	A	1.2	1.3	12.0	1.2
	B	1.4	1.2	11.0	0.8
	C	1.3	1.9	13.0	1.5
	D	1.2	1.0	3.1	0.6
Titanium (percent)	All	1.4	0.7	4.3	0.5
	A	2.2	0.7	2.2	0.5
	B	2.2	0.9	4.3	0.6
	C	1.4	0.6	2.1	0.4
	D	1.5	0.7	2.2	0.4
Manganese (ppm)	All	1,100	748	10,000	684
	A	250	702	7,100	657
	B	1,100	930	10,000	964
	C	1,100	620	2,000	343
	D	1,100	690	4,200	435
Boron (ppm)	All	5.0	24.4	250	28.1
	A	5.0	22.4	200	23.0
	B	5.0	25.2	250	31.3
	C	5.0	31.9	190	28.5
	D	5.0	19.2	250	27.7
Barium (ppm)	All	1,100	700	4,600	440
	A	530	655	4,300	342
	B	670	702	4,600	438
	C	440	611	2,100	267
	D	1,100	831	4,600	613
Beryllium (ppm)	All	1.0	3.5	15.0	1.8
	A	1.0	3.3	15.0	1.8
	B	1.0	3.9	9.7	1.8
	C	1.0	3.9	8.7	2.0
	D	2.0	3.0	6.2	1.3
Cobalt (ppm)	All	11.0	14.2	1,000	29.6
	A	11.0	11.4	68	8.7
	B	12.0	17.8	1,000	53.6
	C	11.0	14.3	41	8.4
	D	13.0	13.2	49	8.9
Chromium (ppm)	All	17.0	42.5	280	39.1
	A	12.0	36.4	250	34.1
	B	11.0	47.5	220	38.3
	C	15.0	50.4	260	46.8
	D	23.0	37.2	280	36.9

Table B - 10

Geochemical Sampling Data: Basic Statics For Selected Elements

Sieved Samples
(Continued)

Element (units)	Sampling Area (see fig. B5)	Mode	Mean	Maximum Sample Value	Standard Deviation
Copper (ppm)	All	12.0	25.2	2,200	73.5
	A	13.0	24.7	1,200	66.0
	B	12.0	29.9	2,200	118.6
	C	12.0	24.8	150	20.5
	D	11.0	20.6	120	17.1
Molybdenum (ppm)	All	3.9	9.7	180	14.9
	A	2.7	8.2	99	12.6
	B	3.8	14.0	130	19.6
	C	10.0	9.4	180	13.4
	D	2.0	6.5	79	9.7
Niobium (ppm)	All	16.0	29.1	870	38.6
	A	24.0	25.7	180	20.4
	B	32.0	44.3	870	65.2
	C	18.0	20.6	86	11.6
	D	12.0	21.7	84	13.6
Lead (ppm)	All	19.0	28.6	1,800	65.0
	A	15.0	35.2	1,800	104.3
	B	19.0	24.4	130	14.2
	C	16.0	28.6	500	61.1
	D	20.0	25.4	400	33.7
Vanadium (ppm)	All	110.0	113.8	1,100	123.5
	A	47.0	94.3	900	106.5
	B	110.0	143.2	1,100	144.1
	C	130.0	97.2	820	103.9
	D	110.0	116.8	1,100	125.2
Zinc (ppm)	All	110.0	96.2	7,100	215
	A	110.0	99.5	7,100	377
	B	110.0	103.5	510	76
	C	110.0	110.5	1,100	121
	D	110.0	70.3	400	43
Cerium (ppm)	All	46.0	166.0	2,900	210.3
	A	46.0	143.7	2,900	225.9
	B	130.0	249.2	1,700	275.9
	C	120.0	132.4	960	90.7
	D	46.0	119.8	1,600	123.1

TABLE B - 11

Geochemical Sampling Data: Basic Statistics For Selected Elements

Heavy Mineral Concentrates

Element (units)	Sampling Area (see Fig. B5)	Mode	Mean	Maximum Sample Value	Standard Deviation
Magnesium (percent)	All	1.1	2.5	65.0	3.1
	A	1.2	2.6	65.0	4.3
	B	1.1	2.1	17.0	2.0
	C	1.8	3.2	24.0	3.3
	D	1.6	2.1	10.0	1.5
Titanium (percent)	All	1.5	2.0	20.0	2.1
	A	2.3	2.1	20.0	2.1
	B	2.2	2.9	20.0	2.7
	C	1.4	0.7	4.0	0.7
	D	1.5	1.7	6.9	1.1
Manganese (ppm)	All	1,200	3,611	20,000	4,074
	A	1,700	4,200	20,000	4,448
	B	2,000	5,090	20,000	4,682
	C	1,200	1,350	20,000	1,918
	D	1,300	2,996	20,000	3,045
Silver (ppm)	All	0.9	1.9	100	5.9
	A	0.9	2.2	70	6.1
	B	0.9	1.8	36	3.2
	C	0.9	1.6	70	5.2
	D	0.9	1.9	100	8.3
Barium (ppm)	All	1,300	1,105	9,300	1,498
	A	1,300	979	9,300	1,312
	B	1,300	1,179	9,300	1,179
	C	1,100	1,001	9,300	1,098
	D	1,300	1,267	9,300	1,626
Beryllium (ppm)	All	2.0	3.8	87.0	6.4
	A	2.0	4.3	72.0	6.9
	B	2.0	4.3	77.0	6.2
	C	2.0	3.3	87.0	7.5
	D	2.0	2.9	81.0	4.9
Cobalt (ppm)	All	20.0	49.3	2,000	78.1
	A	20.0	46.8	200	37.7
	B	27.0	63.5	2,000	130.9
	C	23.0	35.5	300	33.4
	D	16.0	46.5	350	46.9
Chromium (ppm)	All	120	112	1,500	129
	A	140	129	970	133
	B	130	125	780	96
	C	16	106	1,500	191
	D	110	79	680	76

TABLE B - 11

Geochemical Sampling Data: Basic Statistics For Selected Elements

Heavy Mineral Concentrates
(Continued)

Element (units)	Sampling Area (see fig. B5)	Mode	Mean	Maximum Sample Value	Standard Deviation
Copper (ppm)	All	110	84	7,200	294
	A	110	100	7,100	380
	B	110	118	7,200	389
	C	36	47	290	42
	D	15	53	250	43
Molybdenum (ppm)	All	2.0	14.9	580	26.6
	A	12.0	18.2	320	24.7
	B	2.0	19.3	230	22.9
	C	2.0	9.2	580	38.0
	D	2.0	10.1	240	18.5
Lead (ppm)	All	38.0	111.5	7,000	325
	A	31.0	136.6	2,400	218
	B	38.0	84.1	770	102
	C	19.0	98.1	3,700	359
	D	19.0	125.8	7,000	528
Tin (ppm)	All	9.3	15.3	610	21.7
	A	9.3	17.5	610	34.9
	B	9.3	18.2	180	17.0
	C	9.3	10.3	54	4.8
	D	9.3	13.2	81	9.2
Zinc (ppm)	All	110	238	9,000	350
	A	110	292	9,000	563
	B	190	301	1,600	217
	C	120	157	2,400	227
	D	120	158	880	106
Potassium (percent)	All	1.5	1.9	7.3	0.8
	A	1.4	2.1	7.3	1.0
	B	1.5	1.8	3.9	0.6
	C	1.7	1.8	4.5	0.7
	D	1.7	2.1	5.6	0.8
Cerium (ppm)	All	1,100	1,015	17,000	1,288
	A	1,100	954	10,000	1,161
	B	1,300	1,619	17,000	1,708
	C	93	384	2,800	308
	D	1,400	883	11,000	1,020

5. ENCODING DATA

5.1 GRID SYSTEM FOR RECORDING DATA

The base maps used for the California Desert Planning Project are the USGS Map Series V502, Universal Transverse Mercater (UTM) Projection, scale 1:250,000. With the UTM grid system, any location can be uniquely identified as shown below and in Figure B - 6. Figure 1 of the main report shows the UTM Blocks for the CDCA. UTM locations are defined by the following (References 62 - 75):

$$\text{NNA BB } M_1M_2M_3M_4\ L_1L_2L_3L_4$$

where:

NNA - is the grid zone designator (The entire CDCA is in grid zone 11S. It is, therefore, not coded)
BB - is the 100 kilometer by 100 kilometer square identifier or "UTM Block"
M - is the easting distance from the zero line of the UTM block
  M_1 - is tens of kilometers
  M_2 - is kilometers
  M_3 - is hundreds of meters
  M_4 - is tens of meters
(NOTE: if only 2 Ms appear it is assumed they are M_1 and M_2.)
L - is the northing distance from the zero line of the UTM block.
  L_1 - is tens of kilometers
  L_2 - is kilometers
  L_3 - is hundreds of meters
  L_4 - is tens of meters
(NOTE: if only 2 Ls appear, it is assumed they are L_1 and L_2).

For the purpose of recording data, each UTM block is divided in cells of 2 km square. There are 50 x 50 = 2500 such cells per UTM block. A unique identifier for each cell is the two - letter UTM block, a two - digit column number and a two - digit row number. Figure B - 7 illustrates the cell numbering system.

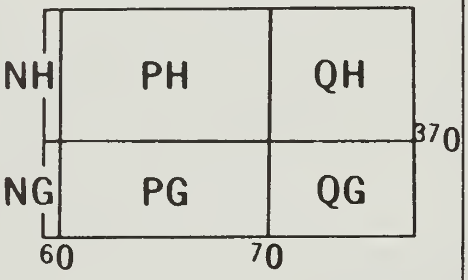
FIGURE B - 6

Explanation Of UTM System*

GRID ZONE DESIGNATION:

11S

100,000 M. SQUARE IDENTIFICATION



IGNORE the SMALLER figures of any grid number; these are for finding the full coordinates. Use ONLY the LARGER figure of the grid number; example: 3660000

TO GIVE A STANDARD REFERENCE ON THIS SHEET TO NEAREST 1000 METERS

SAMPLE POINT: RIPLEY

1. Read letters identifying 100,000 meter square in which the point lies.	QH		
2. Locate first VERTICAL grid line to LEFT of point and read LARGE figure labeling the line either in the top or bottom margin, or on the line itself:		1	
Estimate tenths from grid line to point:		8	
3. Locate first HORIZONTAL grid line BELOW point and read LARGE figure labeling the line either in the left or right margin, or on the line itself:			1
Estimate tenths from grid line to point:			2
SAMPLE REFERENCE:	QH1812		
If reporting beyond 18° in any direction, prefix Grid Zone Designation, as:	11SQH1812		

SALTON SEA, CALIF.; ARIZ.

1959
REVISED 1969

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* Copied from the Salton Sea, California; and Arizona Map Sheet (Reference 56).

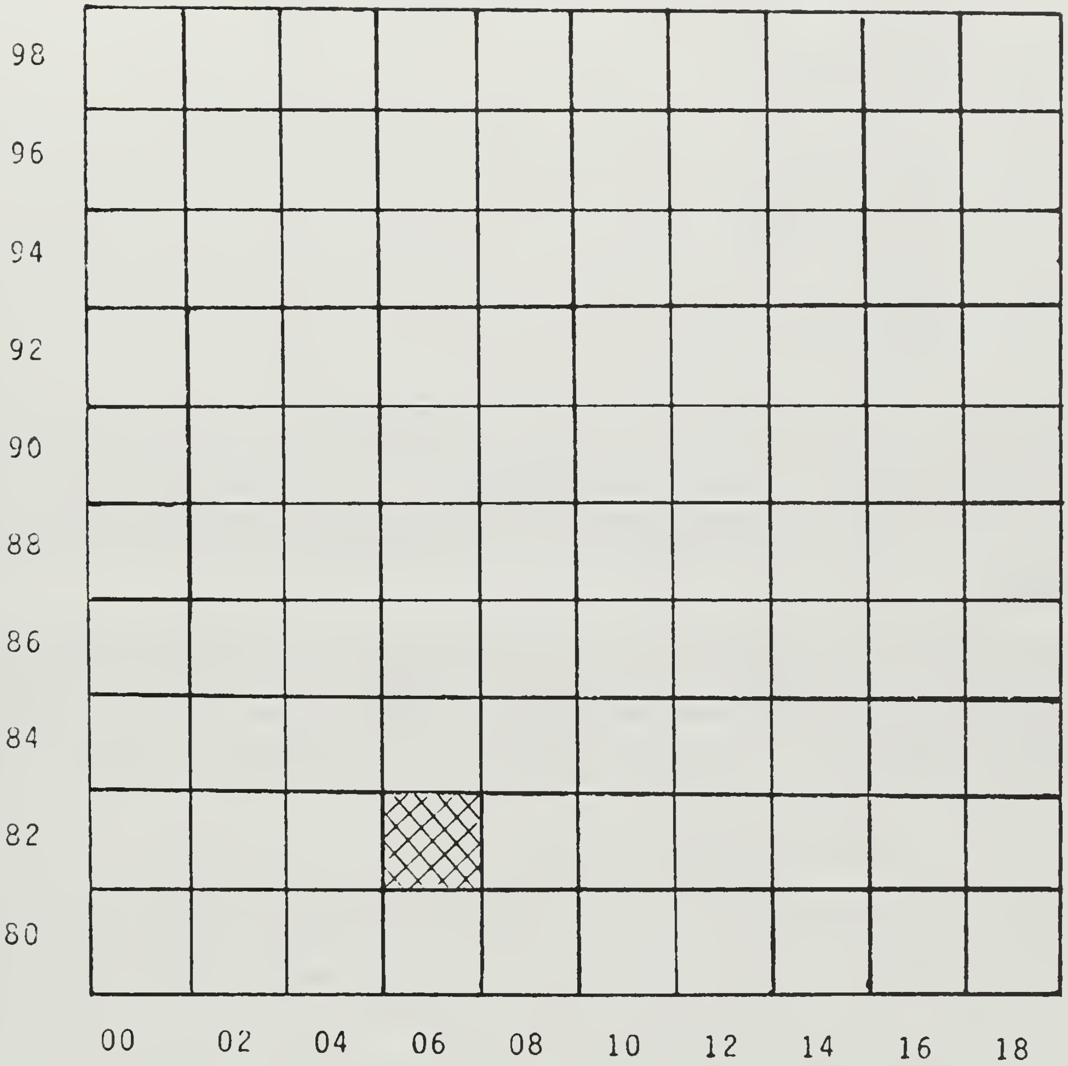

FIGURE B - 7

Portion Of A UTM Block Divided Into Cells
UTM Block PG

(Hatched cell is PG0682)

5.2 USE OF GEOLOGIC MAPS

The 1:250,000 scale Geologic Maps of California, published by the CDMG were used to determine the geologic variables of each cell. The following map sheets, covering the entire CDCA, were used:

- Mariposa
- Fresno
- Death Valley
- Trona
- Kingman
- Bakersfield
- Los Angeles
- San Bernardino
- Needles
- Santa Ana
- Salton Sea
- San Diego - El Centro

Since geologic maps are the basis for some of the geologic variables as defined by this study, map scale influences accuracy. The detail of each map sheet depends upon the amount of information available, the professional interpretations employed at the time of compilation, the drafting techniques used, the accuracy of reproduction and the scale of the map. In general, larger scales allow more accurate and detailed representation of the geology.

Portions of the CDCA are covered by geologic maps at scales larger than 1:250,000 (References 103 through 135). These maps were used to check the interpretation of the 1:250,000 CDMG maps. However, these larger - scale maps were not used for encoding geological variables because different degrees of detail would introduce a degree of statistical bias.

5.3 PREPARATION OF GRAVITY DATA

The gravity data received from Dr. Shawn Biehler, University of California at Riverside, consist of Bouguer gravity in milligals as computed at points that form a diamond pattern (see Figure B - 8 below) for most of the CDCA. For ease of computer manupulation, 1,000 milligals were added to each gravity reading. This had no influence on final results. It was only a computational convenience. The data for block PK were added from the Bouguer Gravity Map of California, Kingman Sheet, 1:250,000 (Reference 59). The data for UTM blocks LJ, LK, MK and parts of blocks NG and PG were determined from the GE "Complete Bouguer Anomalies" contour map (Reference 78) which was based on Dr. Biehler's work.

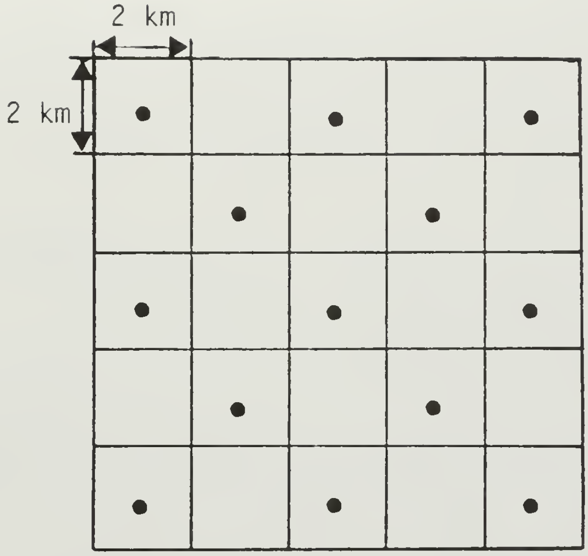

FIGURE B - 8

Diamond Pattern of Gravity Data

Since geostatistical routines were performed on a 4 - km by 4 - km cell basis, the two values in each 4 - km cell were averaged and included in the geologic data file for 4 - km cells. This means that, while gravity data are contained in the geologic data file for 4 - km cells, they are not contained in the data file for the 2 - km cells. In cases where only one value was provided for a 4 - km cell (on the borders of sections where no data were provided), that single value was taken for the entire cell (Reference 60).

5.4 ENCODING GEOLOGIC AND GEOPHYSICAL VARIABLES

5.4.1 Encoding System

The variables were encoded as follows:

1. UTM blocks and cells were drawn on the CDMG geologic maps.
2. Using a fine - mesh counting grid, the proportion of each lithologic unit was estimated for each cell.
3. The length of contacts and the number, length and curvature of each type of fault was recorded for each cell.
4. Data were encoded, verified and placed on magnetic tape.

Table B - 12 shows the units used for encoding each variable.

5.4.2 Fault Curvature

The curvature of a fault is measured by the smallest radius of any arc of a fault in a cell. That is, the degree of curvature in a cell is represented by the portion of a fault which, if continued to form a circle, would have the smallest radius of any such circles formed in the cell. Five classifications (Table B - 13) were used: I indicates no curvature or a straight fault; 9 indicates a radius of one kilometer (i.e., a fault that might form a complete circle inside one cell).

Faults are not uniformly curved and often do not fit nicely into one of the categories described. Some of the types of faults that are difficult to classify and their classifications are shown in Figure B - 9.

5.5 ENCODING LINEAMENT VARIABLES

As discussed in Section 3 of this appendix, selection of appropriate lineament variables required several analytical steps. In order to allow greater flexibility of variable selection and testing, a system was developed for encoding lineaments that did not predetermine which variables would be ultimately selected. Under this system lineaments are described by the coordinates of the end - points of the closest fitting straight line segments. From these end - points, lineament variables are calculated by computer on a cell - by - cell basis. This system permits modification of the variables without changing the data base and, therefore, without additional encoding.

The end - points of all lineament segments were encoded as follows:

1. UTM blocks were drawn on each of the lineament maps.
2. Each lineament was numbered for each of the four lineament types (LANDSAT, gravity, Skylab, aerial).
3. Each lineament was approximated by one or more straight - line segments.
4. Using a fine - mesh UTM grid overlay, the coordinates of the end - points for each straightline segment were determied.
5. Segment end - point data were encoded and verified.

From the lineament segment end - point data, the length, azimuth and intersection of lineaments were calculated by computer. The selected lineament variables (see Section 3) were determined for each cell for each of the four lineament types. Finally, a file was created containing the value of each of the 20 variables for each lineament type (80 variables total) for each 2 - km by 2 - km cell of the CDCA.

TABLE B - 12

Geologic And Geophysical Variable Quantifiers

Variable	Numbers	Quantifier	Units
Geologic map units	1-18	Proportion	25ths
Geologic contacts	19-33	Length	0.4 km
Fault lengths	34,36	Length	0.4 km
Number of faults	35,37	Number	no units
Fault intersections	38	Number	no units
Fault curvature	39,40	See description in text	
Bouguer gravity	41		mgals + 1000

TABLE B - 13

Measurement Of Degree Of Fault Curvature

Curvature Measure	Definition
1	Straight line
3	Arc with 8 to 4 km radius
5	Arc with 4 to 2 km radius
7	Arc with 2 to 1 km radius
9	Arc with 1 km radius or smaller

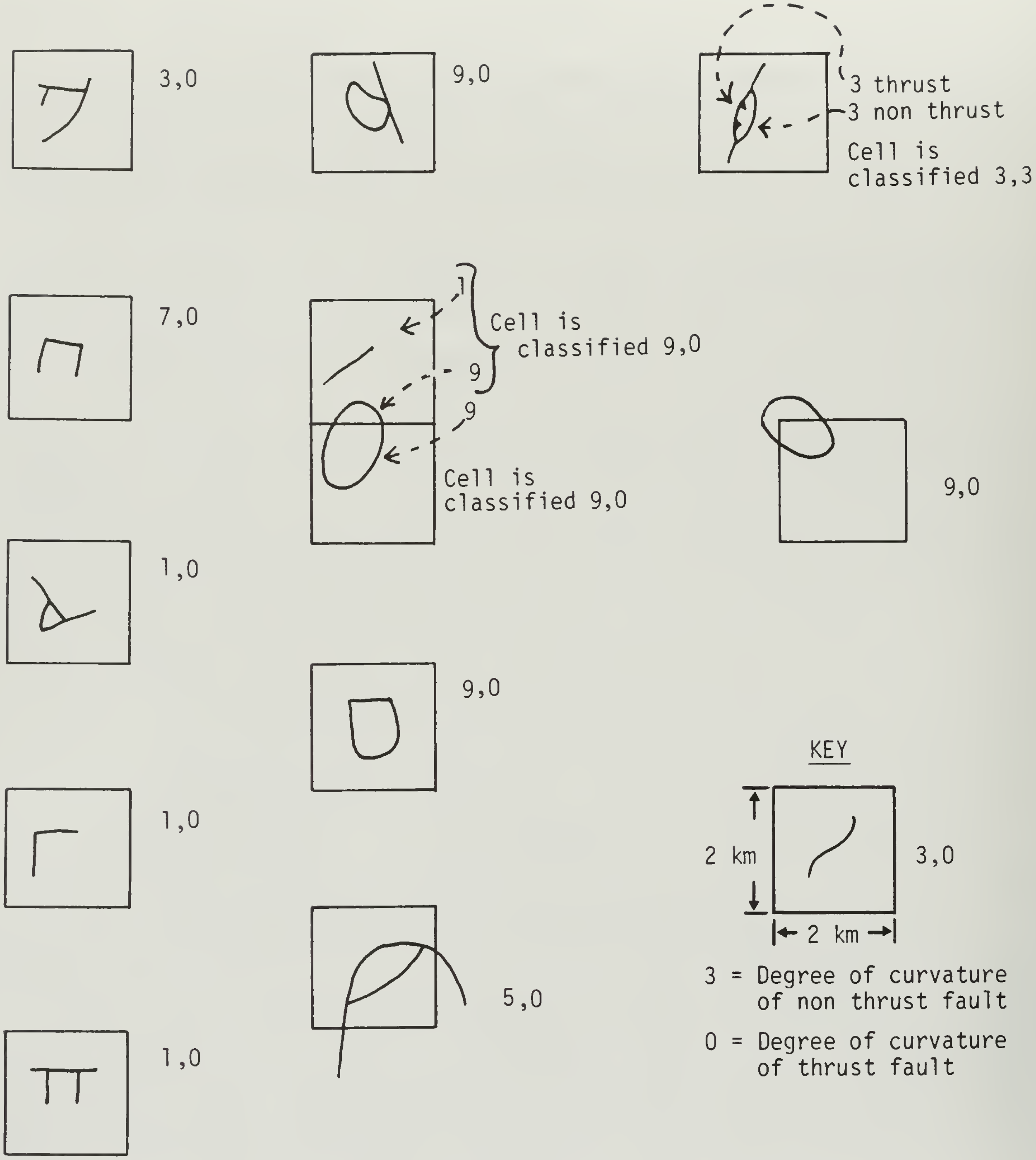

FIGURE B-9

Sample Classifications Of Fault Curvature

5.6 ENCODING TONAL ANOMALIES

As part of a contract with BLM, GE has mapped areas of tonal anomalies interpreted from LANDSAT images. These areas might be representative of hydrothermal alterations (Reference 139). No field checks have been made yet to verify the correspondence between the tonal anomalies and hydrothermal alterations. Tonal anomalies were mapped in three areas of the CDCA, each approximately 80 kilometers by 80 kilometers (see Figure B - 10). In total these areas represent less than 20 percent of the CDCA.

These variables were encoded for tonal anomalies as follows (see Table B - 6):

1. **Total size of anomalies touching the cell**
   Using a fine - mesh counting grid, the size of each tonal anomaly was determined. The total size of all tonal anomalies partially or completely contained within a 4 - km by 4 - km cell was summed and assigned to that cell as the first variable.

2. **Size of anomalies within the cell**
   Using the fine - mesh grid, the size of that part of each anomaly contained within a cell was determined. The sum of these values for each cell is the second variable.

3. **Number of anomalies within the cell**
   The last variable is the number of tonal anomalies partially or completely within a cell.

5.7 ENCODING GEOCHEMICAL DATA

Geochemical samples were collected over scattered locations in four areas. The sample locations are approximately 10 kilometers apart on the average, but this distance varies greatly. In order for the data to be useful for discrimination of mineral potential, using DFA, a value for each element must be assigned to each cell (4 - km by 4 - km). If this is not done, DFA will assume zero values where sample data do not exist. Thus, it was necessary to interpolate a value for each 4 - km by 4 - km cell. In addition, it was necessary to provide contour maps of the geochemical sampling results to the expert panel. Sampling results for 30 elements (15 sieved samples, 15 heavy mineral concentrate samples) were mapped using the SURFACE II contouring program at the Stanford Center for Information Processing.

For the interpolation at a particular cell as well as interpolation for contouring (see Reference 140 for an explanation of the contouring routine), sample values were weighted by the inverse of the distance between the cell and the sample locations taken to the sixth power. This weighting places a strong emphasis on the sampling data and insures that anomalies will not be lost due to interpolation. A grid spacing of four kilometers was used. No transformations were made on the data. Frequently, a log - transform is applied to geochemical sampling data, but since the USGS also provided BLM with an analysis of the same data using a log - transform, that effort was not duplicated.

Each of the four sampling areas was treated separately, so 120 runs were necessary: 15 elements (sieved) plus 15 elements (heavy mineral concentrate) (see Table B - 9) times four areas. The interpolated values were then assigned to the appropriate cells.

These values were also contoured and provided to BLM as maps at 1:250,000 and 1:500,000 scales. The maps show contours of the following for each element:

- Mean
- One standard deviation above the mean
- Two standard deviations above the mean
- Three standard deviations above the mean
- Four standard deviations above the mean

The mean and standard deviation shown on a particular map are the mean and standard deviation of the sample values of the element taken in the sample area represented by the map (see Tables B - 10 and B - 11). Thus, the contour levels for an element may not be comparable from one area to another.

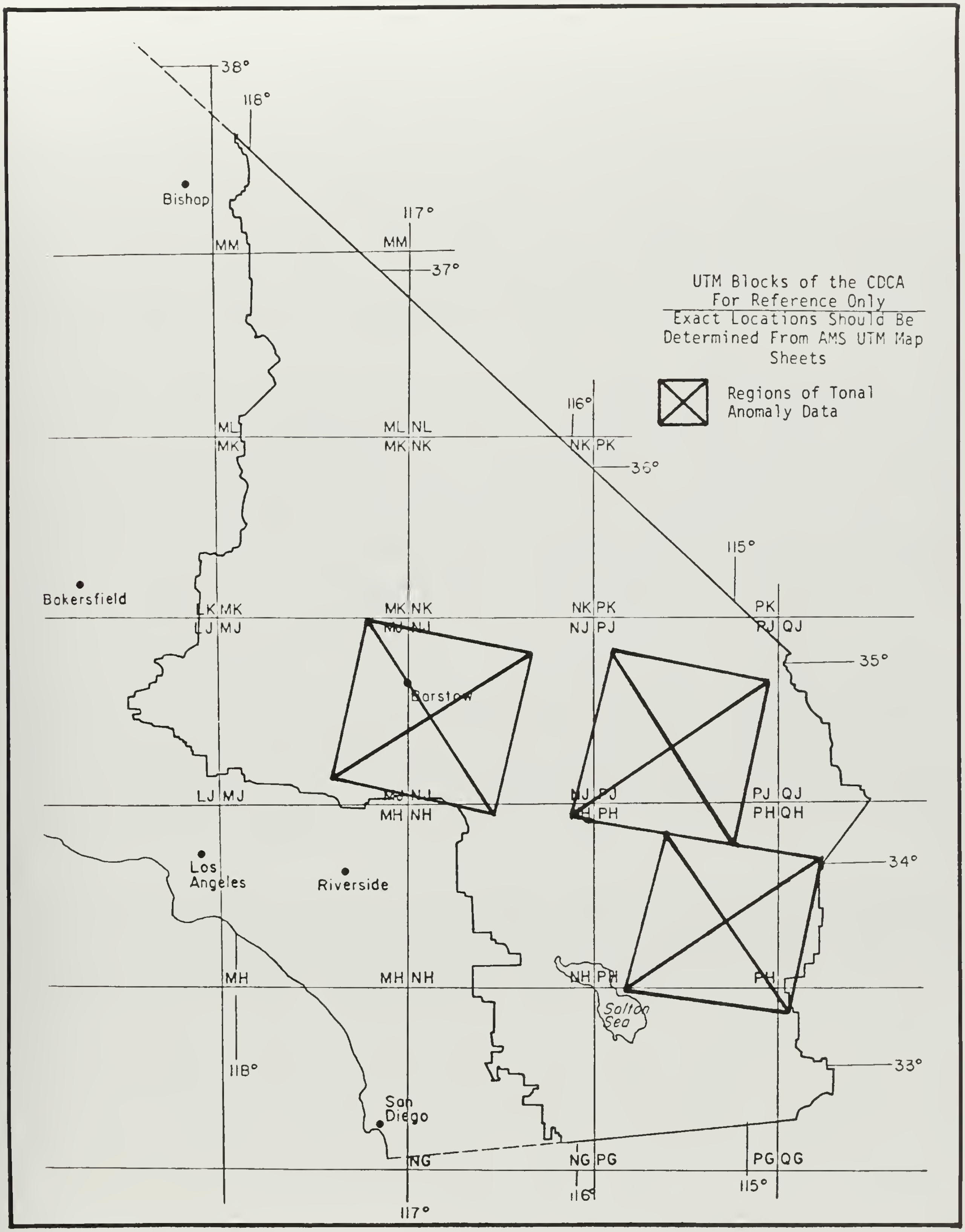

FIGURE B - 10

Map Of CDCA Showing Regions Of Tonal Anomaly Study

6. TREATMENT OF AIRBORNE MAGNETIC AND RADIOMETRIC DATA

Under the National Uranium Resource Evaluation (NURE) program of the Department of Energy (DOE), airborne gamma - ray spectrometeric and aerial magnetic data are being collected on a uniform basis over a large portion of the United States. To date within the CDCA, data have been collected and processed covering the Goldfield (Mariposa), Death Valley, Trona, Kingman and Needles 1° by 2° quadrangles. Bismuth (^{214}Bi) Thallium (^{208}Tl), and Potassium (^{40}K) and aeromagnetic readings for these quadrangles were provided by BLM in "stacked profile" (hard copy graphics) format and digitized. The data were digitized by TERRADATA at the BLM Desert Plan Staff office in Riverside, California, using BLM computer facilities.

Each flight line flown to collect the data corresponds to four stacked profiles: one each for bismuth, thallium, potassium and magnetic. Flight lines are approximately five kilometers apart. In all but the Death Valley Quadrangle, the flight lines are oriented in an east - west direction. Because of terrain conditions in the Death Valley quadrangle, the flight lines are oriented north - south. In all quadrangles, several tie lines were flown perpendicular to the flight lines. There are over 200 flight lines and tie lines in all. Approximately 100 points were digitized for each line on the average. More points were digitized for flight lines that exhibit wide or rapid variations. Collection techniques, collection equipment, atmospheric conditions at the time of data collection and flight altitudes at the time of collection vary from quadrangle to quadrangle. The aeromagnetic data are in gammas. The other data are in counts per second.

For visual interpretation, contour maps of the readings were then produced using the SURFACE II software package at the Stanford Center for Information Processing and provided to BLM at 1:250,000 and 1:500,000 scales. Contour maps of the bismuth to thallium ratio were also produced. These maps were also used by the expert panel. In contouring the aerial data, a grid size of 4 kilometers was used. Results for each cell were interpolated from nearby cells using the inverse of the distance to the sixth power as the interpolation algorithm. (See Reference 140 for an explanation of the contouring routine).

Despite DOE's strategy for uniform data collection and processing, the airborne data vary significantly from quadrangle to quadrangle. This may be the result of the various altitudes, aircraft and other equipment employed. Because of the variability of data and the fact that only about 60 percent of the CDCA is covered by airborne data, this information was used by the expert panel but was not used for DFA.

- APPENDIX C -

GEOSTATISTICAL ANALYSIS

I. INTRODUCTION

In general terms, the geostatistical classification involves the application of statistical and analytical procedures to the reported occurrence data, and to the geologic, geophysical, geochemical and lineament data described in Appendices A and B. The geostatistical method selected for this study was discriminant function analysis (DFA). The results of applying this procedure are statistical inferences regarding the likelihood of "occurrence" of one or more Geology-Energy-Mineral (G-E-M) resources throughout the area of the California Desert Conservation Area (CDCA).

In using the results of the geostatistical analysis, the following precautions should be considered:

- Geostatistical analysis for all types of G-E-M resources known to occur in the CDCA is not possible because few occurrences have been reported for some commodities and because the occurrence of some commodities is dependent on factors other than geology.
- The occurrence, geological, geophysical, geochemical and lineament data used in the approach are subject to error as discussed in Appendices A and B.
- All statements of probability involve the likelihood of any one of a set of events occurring. Thus, for example, even if the probability of not drawing the two of hearts from a deck of cards is 51/52 or over 98 percent, it is still possible to draw the two of hearts. Likewise, if an area is classified as an occurrence area with a probability of 99 percent, it is still possible that no resource will be found there.

This report is the result of three separate studies. The first study was a geostatistical analysis using the occurrence data described in Appendix A as the dependent variables and the first 42 geologic and geophysical variables described in Appendix B as the independent variables. For this first study, three geostatistical techniques were used: regression, cluster analysis and DFA (Reference 94). To assess the validity or confidence of the statistical results, it is desirable to have independent variables that are normally distributed. The independent variables, as compiled, are not normally distributed. Therefore, as an experiment of the first study, several transformations were applied (square root, arcsin and log) to the independent variables in an effort to make their distributions approach normality. The results of the experiment showed that no improvement in the statistical significance of the classifications was obtained, so no transformations were applied in the subsequent studies.

The second study involved the addition of the lineament variables to the set of independent variables and the use of two geostatistical techniques: D-square similarity measure and DFA (Reference 138). One result of the first two studies was that DFA was determined to be the best technique for classification.

The final study involved the addition of the geochemical and tonal anomaly data described in Appendix B to the set of independent variables and the use of DFA as the only geostatistical technique. Since the tonal anomaly and geochemical data were not available for the entire CDCA (see Appendix B) they were considered only in the regions where they were available.

This report is the summary of all these efforts. Section 2 of this appendix presents a description of discriminant function analysis, Section 3 describes the preliminary analysis of the independent variables required to insure the best classification results. The final classification results of the entire CDCA are discussed in the main report. The geochemical and tonal anomaly data were not used in those final classifications. The reason for eliminating the tonal anomaly data is given in Section 3.4 of this appendix. The reasons for eliminating the geochemical sampling data are given in Section 3.5.

2. DISCRIMINANT FUNCTION ANALYSIS (DFA)

2.1 PRINCIPLES OF DFA

A simplified explanation of DFA is presented in Section 3.1 of the main report. More information on DFA is in References 96 through 102.

DFA is a technique for assigning members of some set to a class. In this study the members of the set were the geographic cells (4 - km by 4 - km) in the CDCA, and the two classes used were: mineral resource potential and no mineral resource potential. The assignment is based on a relationship or correlation that can be identified between a dependent variable (reported mineral occurrences) and a set of known independent variables (geologic, geophysical, geochemical and lineament data, etc.). This relationship, called a discriminant function, is measured using a computer for a portion of the CDCA called the "training set." The training set is merely a subset of the entire area that is representative of the geology and mineral environment of the region as a whole. The selection of the training set is discussed in more detail in Section 2.3. A brief discussion of the calculation of the discriminant function is given in Section 2.2.

The training set cells with reported occurrences (designated "occurrence cells") are taken to be indicative of mineral resource potential. Cells with no reported occurrences (designated "non - occurrence cells") indicate no mineral resource potential. The discriminant function takes the values of the independent variables in each cell in the training set and calculates a score. If the discriminant function is valid, the scores of the known occurrence cells will be clustered, the scores of the non - occurrence cells will be clustered and the two clusters will not be close together. The mean score of each cluster, called the group mean, is calculated. The group 1 mean is the mean value of the scores of the occurrence cells. The group 2 mean is the corresponding value for the non - occurrence cells. One of three measures applied to test the validity of the discriminant function is the statistical significance of the separation between the group means. This is measured using an F - test (see Appendix D).

Next the discriminant function is applied to the independent variables of every cell in the CDCA, including those in the training set, to derive a score for each cell. The scores are compared to the group means. Each cell is then classified into the group which has the group mean closest to the cell's score. The second measure of the validity of the discriminant function is the percentage of known occurrence cells in the training set that are correctly classified by the discriminant function into the mineral resource potential category. The third measure of validity, and one might argue the acid test, is the percentage of known occurrence cells <u>not</u> in the training set, correctly classified in the mineral resource potential category. Notice that the corresponding tests for non - occurrence cells are not used, i.e., the percentage of non - occurrence cells correctly classified in the no mineral resource potential category. The reason for this is the uncertainty that a cell with no reported occurrences has no mineral potential. Indeed that cell may simply never have been explored. On the other hand there is reasonable certainty (not 100 percent) that a cell with a reported occurrence does have mineral potential.

The final result of DFA is the calculation of a probability for each cell. This probability is a measure of how close that cell's score is to the group mean of the group to which it has been assigned. A probability of 100 percent indicates that the score is identical to the mean. A 90 percent probabilty indicates that the score is very close to the group mean, but not exactly the same. A 50 percent probability says the score is exactly between the two group means. The probability assigned to each cell is called the probability of correct classification. The distinction between the probability of correct classification and the probability of occurrence is that the former only measures how closely a score matches a calculated mean, while the latter also measures the correspondence between the group means and the real geologic environment of the mineral potential classes. Therefore, a key assumption in the application of DFA is that the discriminant function does, in fact, correspond mathematically to the geologic factors affecting mineralization. Because of this, separate discriminant functions are required to assess the potential of minerals not normally found in similar geologic environments. Thus, in this study, separate analyses were performed for gold; iron; manganese; tungsten and the combination of copper, lead, silver and zinc. The last group, referred to as the "hydrothermal" case, can be combined because the elements often occur in similar geologic environments.

2.2 CALCULATION OF A DISCRIMINANT FUNCTION

Discriminant function analysis (DFA) is the statistical technique used in this study to classify 4-km by 4-km cells according to the likelihood of occurrence of mineral resources. This method was used to discriminate between two categories of mineral occurrence on the basis of a number of geologic, geophysical, geochemical and lineament parameters. By determining relationships between these parameters and mineral occurrences in a subset of cells of the entire area (called the "training set"), these relationships were applied to the entire area.

The method begins with the assumption that some set $(x_1, \ldots, x_k)$ of variables, called "discriminators", can be chosen whose values are closely related to membership properties of the cells in each of the occurrence categories. In our case, the discriminators are the areal percentage of various lithologic units, length of faults, length of contacts between lithologic units, fault curvature, Bouguer gravity, LANDSAT lineaments and geochemical sampling data. (See Appendix B for a discussion of these features.) Using the values of the discriminators and the membership properties of the training cells, the technique yields a linear function of the form

$$Y(x_1, \ldots, x_k) = a_1 x_1 + \ldots, + a_k x_k \qquad \text{(C-1)}$$

where values for each a_j are chosen so that the means $\overline{Y}_i$, of Y for all cells in the training set in occurrence category i are maximally separated relative to the overall variation of Y (reference 95). For example, if there are two populations whose sample sizes (number of training cells) are n_1 and n_2, then the separation between the means is measured by $(\overline{Y}_1 - \overline{Y}_2)^2$. The overall variation of Y is:

$$\text{Var } Y = \sum_{j=1}^{n_1} (Y_{1j} - \overline{Y})^2 + \sum_{j=1}^{n_2} (Y_{2j} - \overline{Y})^2$$

where $\overline{Y}$ is the mean of Y over all cells in the training set and Y_{ij} denotes the value of Y for the j^{th} individual in category i.

The discriminant function is then the linear combination of the form of equation (C-1) above which maximizes:

$$\frac{(\overline{Y}_1 - \overline{Y}_2)^2}{\mathrm{Var}\ Y}$$

When Y is thus chosen, the means $\overline{Y}_1$ and $\overline{Y}_2$ are computed for the sample population, and some intermediate value is chosen as the point best discriminating population 1 from population 2. Sometimes a clear choice of this intermediate value is not possible, and the midpoint $(\overline{Y}_1 + \overline{Y}_2)/2$ is chosen for convenience.

The Statistical Package for the Social Sciences (SPSS) (Reference 96), developed at the University of Chicago and available at the Stanford Center for Information Processing, contains the program DISCRIMINANT which was used in our analysis. DISCRIMINANT has capabilities to perform discriminant analysis on a number of populations and discriminators. In our study, two population category analyses suffice; this requires the computation of one discriminant function. (The number of discriminant functions required is the lesser of the number of discriminators, or the number of populations, minus one) (Reference 96).

In the present application, DISCRIMINANT selects discriminators to be used one at a time to maximize $|\overline{Y}_1 - \overline{Y}_2|$ (absolute value), called the Mahalanobis distance, D^2, until inclusion of further discriminators adds negligible separation. Once the discriminant function has been determined, DISCRIMINANT is used to classify each 4 - km by 4 - km cell into its predicted occurrence category. Each cell in the population is classified, including the training cells whose correct classification is known. The percentage of training cells which are correctly classified by DISCRIMINANT is one measure of the capability of the discriminant function to differentiate among categories.

2.3 SELECTION OF TRAINING SET

There are two main criteria for the training set:

- o It must contain a large enough number of occurrence and non - occurrence cells for the discriminant function to identify patterns or combinations of the independent variables that allow it to distinguish between occurrence and non - occurrence cells.

- o It must contain cells representative of all the geologic environments in which the commodity being considered might be found.

The reason the entire area is not used as the training set is to allow a test of the predictive ability of the discriminant function. That test, a powerful indicator of the validity of the discriminant function, is the percentage of known occurrence cells not in the training set that are correctly classified.

To balance these criteria (large number of occurrence cells vs. test area) the training set was defined to include half of all known occurrence cells and half of the cells with no reported occurrences. Thus, it includes half of the cells of the CDCA. The cells are selected for the training set by choosing alternate cells from the listing of occurrence and non - occurrence cells.

3. VARIABLES USED FOR DISCRIMINANT FUNCTION ANALYSIS

Ninety-four independent variables were compiled for this study. They include 40 geologic, 1 gravity, 20 lineament, 3 tonal anomaly and 30 geochemical variables (see Appendix B). For DFA to work well, these independent variables must satisfy certain conditions:

- They should not be correlated with each other.
- They should occur frequently enough to have a reasonable chance of distinguishing between high and low resource potential.
- They should be correlated with resource potential from a geologic standpoint; i.e., they should be geologically relevant.
- They should be correlated with resource potential from a statistical standpoint; i.e., they should be statistically relevant.

Each of these conditions was considered in this study, as discussed below. The result was a composite set of variables derived from the original 94 variables as shown in Table C-1. The derivation of this composite set is discussed below.

3.1 CORRELATION WITH OTHER VARIABLES

An analysis of the Pearson Product Moment Correlation Coefficient (see Appendix D) of each of the 94 variables with each other variable showed a few situations in which two or more variables were highly correlated. For this study, any correlation coefficients with an absolute value greater than .65 define highly correlated variables. In this case, one of the highly correlated variables was eliminated from DFA applications. In analyzing the distribution of correlation coefficients, there was a significant break at .65, so that value was selected.

Variables 35 and 39 (number and curvature of thrust faults) and 37 and 40 (number and curvature of nonthrust faults) were eliminated because they are highly correlated with Variables 34 (length of thrust faults) and 36 (length of nonthrust faults), respectively. Variables 44 (weighted length of lineament intersections) and 45 (number of lineaments) were eliminated due to their high correlation with variables 43 (weighted number of lineaments that intersect) and 46 (length of lineaments), respectively. Length and number of lineaments in each azimuth class are also highly correlated leading to the elimination of Variables 47-54 (number of lineaments in each of the eight classes). The correlations are summarized in Table C-2. Reference 138 presents additional details of the correlation analysis.

3.2 FREQUENCY OF OCCURRENCE

Variables with coverage of less than two percent of the CDCA or presence in 150 or fewer cells occur too infrequently to discriminate effectively and were considered candidates for combination with other variables. These variables are lithologic units 1, 3, 5, 6, 7, 8, 9, 10, 14 and 17 and contact relationships 21 through 31 (see Tables 2, 3 and 4). However, variables 1 and 10 were maintained as separate variables because they are not similar to any other variable in terms of their geologic relationship to mineral potential. The rationale for variable combination is detailed in the next section.

TABLE C - I

Composite Final Variable Sets
Variable Components

Variable Set	Number	Description
1.	1.	Precambrian granitic rocks.
	2.	Cambrian metamorphic rocks.
	6.	Pre-Cretaceous metasedimentary rocks and pre-Cretaceous metamorphic rocks.
	7.	Paleozoic and Precambrian metavolcanic rocks.
	9.	Pre-Cretaceous metavolcanic rocks (if age cannot be established other than pre-Cretaceous).
3.	3.	Cambrian and late Precambrian sedimentary rocks.
	4.	Ordovician through Mississippian marine sedimentary rocks.
	5.	Pennsylvanian through Permian marine sedimentary rocks.
	8.	Triassic-Jurassic marine sediments.
4.	10.	Mesozoic basic intrusives.
5.	11.	Mesozoic granitic intrusives and pre-Cenozoic granitic and metamorphic rocks.
	14.	Tertiary igneous intrusives (hypabyssal).
6.	13.	Tertiary sediments (marine and non-marine).
7.	12.	Eolian deposits.
	16.	Quaternary sediments.
8.	15.	Tertiary volcanics.
	17.	Quaternary volcanics.
9.	19.	Length of contact between Precambrian granitic rocks (1) and Precambrian metamorphic rocks (2).
10.	20.	Length of contact between Mesozoic granitic intrusives and pre-Cenozoic granitic and metamorphic rocks (11), and either Ordovician through Mississippian marine sedimentary rocks (4), or Pennsylvanian through Permian marine sedimentary rocks (5).
	21.	Length of contact between Mesozoic granitic intrusions and pre-Cenozoic granitic and metamorphic rocks (11) and Triassic-Jurassic marine sediments (8).
11.	22.	Length of contact between Tertiary igneous intrusives (14) and Precambrian granitic rocks (1).
	23.	Length of contact between Tertiary igneous intrusives (14) and Precambrian metamorphic rocks (2).
	24.	Length of contact between Tertiary igneous intrusives (14) and Cambrian and late Precambrian sedimentary rocks (3).
	25.	Length of contact between Tertiary igneous intrusives (14) and Ordovician through Mississippian marine sedimentary rocks (4).
	26.	Length of contact between Tertiary igneous intrusives (14) and Pennsylvanian through Permian marine sedimentary rocks (5).
	27.	Length of contact between Tertiary igneous intrusives (14) and pre-Cretaceous metasedimentary rocks and pre-Cretaceous metamorphic rocks (6).
	28.	Length of contact between Tertiary igneous intrusives (14) and Paleozoic and Precambrian metavolcanic rocks (7).
	29.	Length of contact between Tertiary igneous intrusives (14) and Triassic-Jurassic marine sediments (8).
	30.	Length of contact between Tertiary igneous intrusives (14) and pre-Cretaceous metavolcanic rocks.
	31.	Length of contact between Tertiary igneous intrusives (14) and Mesozoic basic intrusives (10).
	32.	Length of contact between Tertiary igneous intrusives (14) and Mesozoic granitic intrusives and pre-Cenozoic granitic and metamorphic rocks (11).
12.	34.	Length of thrust faults.
	36.	Length of non-thrust faults.
13.	38.	Number of fault intersections.
14.	41.	Gravity value measured at cell center.
15.	43.	Weighted number of LANDSAT lineaments which intersect in cell.
16.	66.	Geochemical Variable: Sieved Magnesium
17.	68.	Geochemical Variable: Sieved Manganese
18.	72.	Geochemical Variable: Sieved Cobalt
19.	73.	Geochemical Variable: Sieved Chromium
20.	74.	Geochemical Variable: Sieved Copper
21.	75.	Geochemical Variable: Sieved Molybdenum
22.	76.	Geochemical Variable: Sieved Niobium
23.	77.	Geochemical Variable: Sieved Lead
24.	78.	Geochemical Variable: Sieved Vanadium
25.	79.	Geochemical Variable: Sieved Zinc
26.	80.	Geochemical Variable: Sieved Cerium
27.	81.	Geochemical Variable: Heavy Mineral Concentrate Magnesium
28.	82.	Geochemical Variable: Heavy Mineral Concentrate Titanium
29.	83.	Geochemical Variable: Heavy Mineral Concentrate Manganese
30.	84.	Geochemical Variable: Heavy Mineral Concentrate Silver
31.	86.	Geochemical Variable: Heavy Mineral Concentrate Beryllium
32.	87.	Geochemical Variable: Heavy Mineral Concentrate Cobalt
33.	88.	Geochemical Variable: Heavy Mineral Concentrate Chromium
34.	89.	Geochemical Variable: Heavy Mineral Concentrate Copper
35.	90.	Geochemical Variable: Heavy Mineral Concentrate Molybdenum
36.	91.	Geochemical Variable: Heavy Mineral Concentrate Lead
37.	92.	Geochemical Variable: Heavy Mineral Concentrate Tin
38.	93.	Geochemical Variable: Heavy Mineral Concentrate Zinc
39.	94.	Geochemical Variable: Heavy Mineral Concentrate Cerium

TABLE C - 2

Highly Correlated Variables

Variables Correlated (Numbers in Parentheses)	Correlation Coefficient
Number of thrust faults (35) with length of thrust faults (34)	0.96
Curvature of thrust faults (39) with length of thrust faults (34)	0.71
Number of nonthrust faults (37) with length of nonthrust faults (36)	0.95
Curvature of nonthrust faults (40) with length of nonthrust faults (36)	0.68
Weighted length of lineament intersections (44) with weighted number of lineaments that intersect (43)	0.84
Number of lineaments (45) with length of lineaments (46)	0.77
Number of lineaments in each azimuth class (47 through 54) with length of lineaments in each azimuth class (55 through 62):	
47 with 55	0.81
48 with 56	0.84
49 with 57	0.79
50 with 58	0.83
51 with 59	0.88
52 with 60	0.77
53 with 61	0.70
54 with 62	0.77

3.3 GEOLOGIC RELEVANCE

Primarily because of their low frequency of occurrence, several lithologic units and contact relationships were combined to form variable sets based upon similar geology (Table C - 1). In addition, one fault variable set was selected by combining the variables length of thrust and nonthrust faults, because no discriminatory power was suggested by separating them in the initial DFA runs. Those variables grouped together are:

- Metamorphic, metasedimentary, and metavolcanic lithologic units (Variables 6, 7 and 9 were combined with Variable 2).
- Marine sedimentary lithologic units (3, 5 and 8 were combined with 4).
- Igneous and granitic intrusive lithologic units (14 was combined with 11).
- Quaternary lithologic units (12 and 16).
- Volcanic lithologic units (17 was combined with 15).
- Contacts involving Mesozoic granitic intrusives or pre - Cenozoic granitic and metamorphic rocks (21 was combined with 20).
- Contacts involving Tertiary igneous intrusives (22 through 33).
- Thrust and non - thrust faults (34, 36)

Variable 42 (number of subcells), which is used as a computational aid alone, was not used as a variable in DFA. Variable 18 (water and unmapped areas) was eliminated because it is not correlated with mineral occurrences and tends to mask the relevant geologic variables. Any statistical relationships that might appear between this variable and mineral occurrences would be coincidence and misleading if used for predictive purposes.

3.4 STATISTICAL SIGNIFICANCE

To measure the importance of the geologic, geophysical, geochemical, tonal anomaly and lineament variables, several tests were made using DFA. For consistent comparison, these tests were made on subsets of the CDCA where data on all variables were available. The purpose of applying these tests was to measure the statistical relevance of each independent variable in indicating G - E - M resource potential.

As discussed in Appendix B, the tonal anomaly and geochemical data are not available for the entire CDCA. The test areas are shown in Figure C - 1. They consist of two separate regions, each approximately 5000 square kilometers. The copper, lead, silver, zinc (hydrothermal) case was used for the test because of the theoretical relationship between tonal anomalies and hydrothermal alterations. Tests were made on several combinations of variables to determine the best set of variables. The results of these tests are shown in Table C - 3 and described below.

Occurrence cells in the training sets are defined by reported occurrences. Non - occurrence cells in the training set are those that remain, and are, thus, more likely to be misclassified. Therefore, to test the significance of the results it is more important to consider the percent of occurrence cells correctly classified (column 1 in

Table C - 3) than the percent of non - occurrence cells correctly classified (column 2). The results of applying DFA to these test areas indicate that:

- Geologic variables provide information (both columns 1 and 2 show high percentages correctly classified).
- Gravity provides information (compare case 2 with case 1, column 1).
- Tonal anomalies do not add any information (compare case 4 with case 2, case 5 with case 3 or case 7 with case 6).
- Geochemical data add information (compare case 6 with case 3).
- Lineament data may add information. The tests are inconclusive in Table C - 3. Comparison of case 3 with case 2 shows improvement due to lineament data in the test of percentage of non - occurrence cells correctly classified (column 2) only. However, comparison of case 5 with case 4 shows some improvement in both tests (columns 1 and 2).

To confirm the results of the tests, DFA was applied in the test areas using all variables for the following additional cases: gold, iron, manganese, tungsten. The results of these additional tests showed:

- Only in the case of iron did any tonal anomaly variable provide any discriminating power and in that case it was only the fourth most important variable, providing less than 8 percent of the discriminating power. Because of the low discriminating power and the fact that tonal anomaly data are available for less than 20 percent of the CDCA, the tonal anomaly variables were not used for subsequent analysis.
- The lineament variables also proved marginally effective in the additional tests. They were maintained for the final classifications of the entire CDCA (see Section 4 of the main report). In further tests using geochemical data, however, to keep the number of variables manageable (with the addition of 30 geochemical variables) only one lineament variable (weighted number of LANDSAT lineaments which intersect in a cell) was maintained (see Section 3.5 below).
- The following geochemical variables provided no discrimination and were eliminated: sieved titanium, boron, barium and beryllium and heavy mineral concentrate barium and potassium.

3.5 ANALYSIS OF GEOCHEMICAL VARIABLES

Previous work (Reference 138) indicated that without the geochemical sampling data DFA could be applied only to the five commodity categories: copper, lead, silver, zinc combined; gold; iron; manganese; and tungsten.

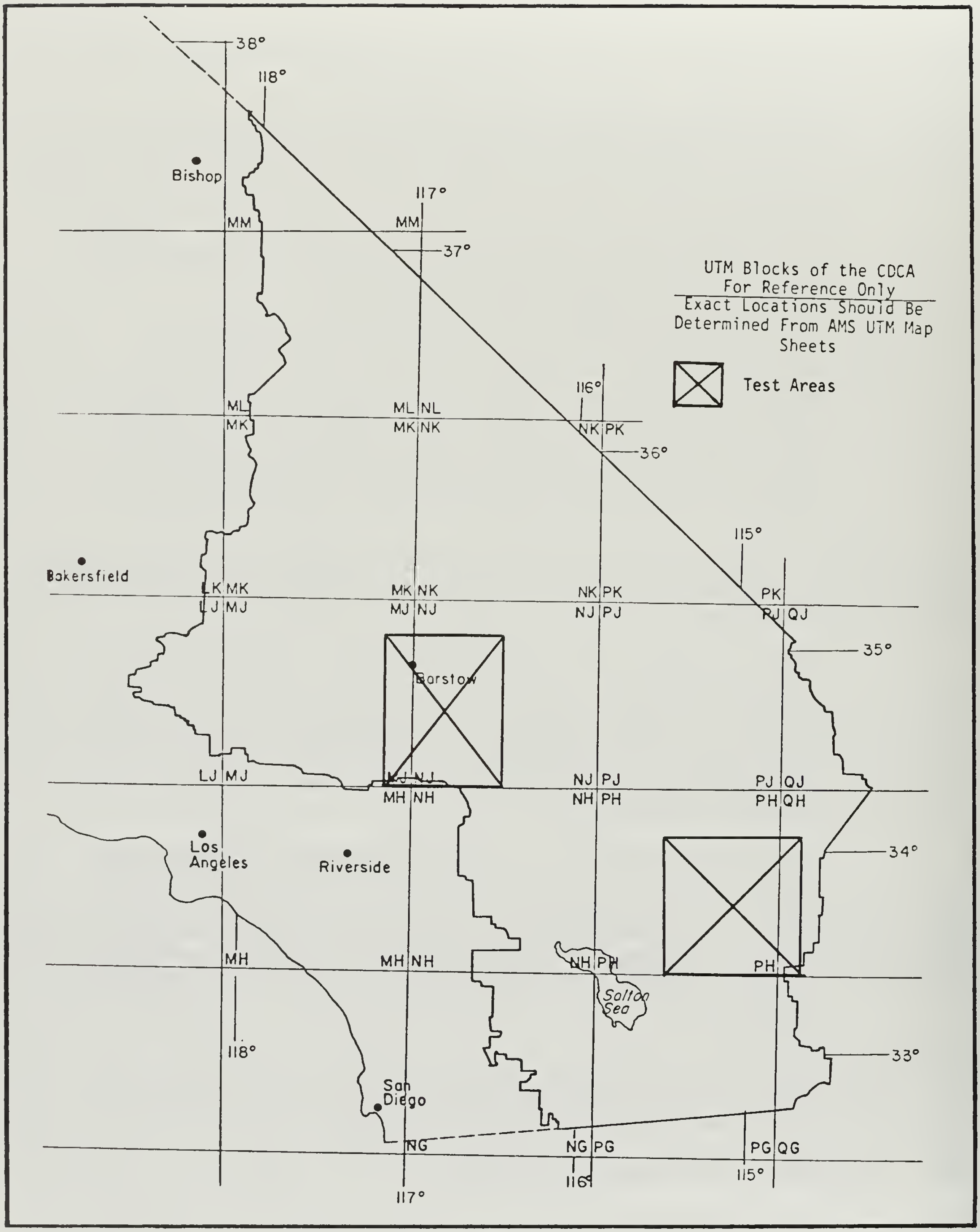

FIGURE C - 1

Test Areas For Variables

TABLE C - 3

Results Of DFA Test Runs To Determine Variable Importance[a]

	Percent of Cells in Training Set Correctly Classified			Number of Cells in Training Set[b] Correctly Classified		
DFA Case: Variables Included	(1) Occurrence	(2) No Reported Occurrence	(3) Both	(4) Occurrence	(5) No Reported Occurrence	(6) Both
1. Geology only	59	82	80	17	232	249
2. Geology, Gravity	69	81	80	20	230	250
3. Geology, Gravity, LANDSAT Lineaments	69	85	83	20	239	259
4. Geology, Gravity, Tonal Anomalies	62	83	81	18	234	252
5. Geology, Gravity, LANDSAT Lineaments, Tonal Anomalies	66	85	83	19	240	259
6. Geology, Gravity, LANDSAT Lineaments, Geochemical	76	87	86	22	247	269
7. All Variables	76	88	87	22	248	270

[a] All tests were made using the hydrothermal case in two separate areas, approximately 5000 km^2 each that have geology, gravity, LANDSAT lineament, tonal anomaly, and geochemical sampling data available. (See Figure C-1.)

[b] Total Number of Cells in Training Set is 312.

The addition of the geochemical data provides the potential to:

1. Improve the significance of the results for the five original categories.

2. Apply DFA to more commodity categories.

Unfortunately, the geochemical data are available for approximately 50 percent of the CDCA only which limits the number of occurrence cells that may be in the training set. Thus, there are more variables for discrimination, but fewer cells on which to base the discriminant function.

The only commodities with the potential for an adequate number of occurrences in the areas where the geochemical sampling took place are:

1. Hydrothermal (Copper, Lead, Silver, Zinc combined)
2. Gold
3. Iron
4. Manganese
5. Tungsten
6. Limestone
7. Talc
8. Borates

and the last six are marginal. The consideration of the last three might be argued on theoretical grounds, but all eight were tested. The results are shown in Table C - 4.

Three tests of significance were applied:

- F - test for significance of separation between the group means (see Appendix D). The 99 percent level of significance was applied.

- Percent of occurrence cells in the training set correctly classified.

- Percent of occurrence cells outside the training set correctly classified.

Borates and manganese fail the F - test. Tungsten, iron, limestone and talc barely pass the F - test and do very poorly on the other two tests. Thus, these six cases were eliminated; only the gold and hydrothermal cases are worth further consideration.

Two refinements to the gold and hydrothermal cases were made which formed six test cases. The cases were restricted to areas where geochemical samples were taken. The six test cases analyzed to test the effectiveness of the geochemical data are:

1. Hydrothermal, all areas

2. Hydrothermal, areas south of Garlock Fault

3. Hydrothermal, areas south of Garlock Fault without geochemical variables

4. Gold, all areas

5. Gold, areas south of Garlock Fault

6. Gold, areas south of Garlock Fault without geochemical variables.

The reasons for considering these six cases are discussed below.

Of the four areas where geochemical sampling was concentrated, three are south of the Garlock Fault and one north. There is evidence to support a theory that different mineralization environments exist north and south of the Garlock Fault (Reference: Mr. Jean Juilland, Desert Plan Staff). To test this theory, separate DFA runs were made for the northern and southern regions using the hydrothermal and gold cases. As shown in Table C - 5, in both cases north of the Garlock Fault the results are poor. Gold fails the F - test. Hydrothermal barely passes the F - test and scores poorly on the classification of occurrence cells outside the training set. These two cases were not considered further. The results south of the Garlock Fault are statistically significant and are discussed below.

To test the importance of the geochemical data to the discriminating power, DFA was applied to the gold and hydrothermal cases in the areas south of the Garlock Fault where geochemical sampling had taken place, but without the geochemical variables included. The results can be compared to the corresponding cases with the geochemical variables. Table C - 5 shows the results were statistically significant with or without the geochemical variables.

Two other measures of the discriminating power of DFA were applied. The first and perhaps the best measure of the effectiveness of DFA is the ratio of percent of known occurrence cells correctly classified by DFA to the percent of area of the CDCA predicted to have high potential. The reason this comparison is important is that a function which assigns high potential to all cells of the CDCA will correctly classify all known occurrence cells, but will at the same time misclassify non - occurrence cells. There is no discrimination. To say the entire CDCA has mineral potential is a true, but useless, statement. It is necessary to have a selective function, i.e., one that assigns mineral potential to a reasonable number of cells and, at the same time, maintains the integrity of known high potential cells (occurrence cells) by assigning a high proportion of them to the occurrence category. In other words, the desirable situation is to have a high percentage of occurrence cells correctly classified, but only a moderate percentage of the CDCA predicted to have high potential. One can then make statements such as "DFA has correctly classified over 60 percent of the known occurrences while assigning high potential to less than 20 percent of the area." If DFA showed no discriminating power, one would expect that 60 percent of the CDCA would have to be classified as having mineral potential in order to classify correctly 60 percent of the known occurrences. Thus, the discriminating power can be measured by calculating the ratio of percent of occurrence cells correctly classified to percent of area classified in the high potential category. This number is referred to as the "high potential" ratio. The larger this number, the better is the discriminatory power of DFA. Table C - 6 summarizes this measure for each of the six cases.

TABLE C - 4

DFA Results — Tests Of Significance On All Areas Of Geochemical Sampling

	Distance between Group Means (a)		Percent of Occurrence Cells Correctly Classified		
Case	F_0	$F_{.01}$	Training Set	Outside Training Set	Entire Area
Hydrothermal	6.21	1.68	57.4	52.1	54.7
Gold (b)	4.81	1.72	62.3	64.7	63.5
Tungsten	2.67	1.73	48.6	27.8	38.4
Iron	2.30	1.72	36.7	24.1	30.5
Manganese	1.62	1.72	57.1	40.7	49.1
Limestone	2.15	1.78	42.3	39.2	40.8
Borates	0.72	1.73	50.0	20.0	35.0
Talc	2.65	1.76	50.0	34.6	42.3

(a) When F_0 exceeds $F_{.01}$, the separation is significant.

(b) Not including placer deposits.

TABLE C - 5

DFA Results — Tests Of Significance On Sub - Areas Of Geochemical Sampling

Case	Distance Between Group Means[a]		Percent of Occurrence Cells Correctly Classified		
	F_0	$F_{.01}$	Training Set	Outside Training Set	Entire Area
North of Garlock Fault					
Hydrothermal	1.73	1.59	70.6	49.0	59.8
Gold[b]	1.29	1.60	68.8	58.1	63.5
South of Garlock Fault					
Hydrothermal	5.31	1.72	59.7	53.2	56.5
Gold[b]	4.53	1.72	58.8	47.1	52.9
Hydrothermal without geochemical variables	11.96	2.32	59.7	56.1	57.9
Gold without geochemical variables	10.44	2.44	58.0	52.1	55.0

(a) When F_0 exceeds $F_{.01}$ the separation is significant.

(b) Not including placer deposits.

TABLE C - 6

DFA Results — Tests Of Effectiveness Restricted To Areas Of Geochemical Sampling

Case	Percent of Occurrence Cells Correctly Classified	Percent of Area Classified with Higher Mineral Potential[a]	Ratio,[b] High Potential	Ratio,[c] Low Potential
Hydrothermal All areas, all variables	54.7	24.0	2.28	.60
Hydrothermal Areas south of Garlock Fault, all variables	56.5	23.8	2.37	.57
Hydrothermal Areas south of Garlock Fault, no geochemical variables	57.9	29.2	1.98	.59
Gold[d] All areas, all variables	63.5	29.1	2.18	.51
Gold[d] Areas south of Garlock Fault, all variables	52.9	23.9	2.21	.62
Gold[d] Areas south of Garlock Fault, no geochemical variables	55.0	24.0	2.29	.59

(a) Probability of correct classification in the occurrence category greater than 50 percent.

(b) This is the ratio of column 1 (percent of occurrence cells correctly classified in areas of geochemical sampling) to column 2 (percent of area classified in the higher mineral potential category).

(c) This is the ratio of percent of occurrence cells classified in the non-occurrence category (misclassifications) to percent of area classified in the lower mineral potential category. It is 100 minus the entry in column 1 divided by 100 minus the entry in column 2.

(d) Not including placer deposits.

For comparison, a similar number was computed (last column of Table C - 6) to measure the ratio of the percent of occurrence cells in the low potential category to percent of area assigned low potential. The lower this number, the better is the discriminating power of DFA. Comparison of the last two columns in Table C - 6 reveals a significant discriminating ability. If there were no discriminating ability, all the entries in the last two columns would be expected to have values very close to one. Instead, the "high potential" ratios are all near 2.0 or higher and the "low potential" ratios are near 0.6 or lower.

Further examination of Table C - 6 shows:

- There is a small improvement in the hydrothermal classification results obtained by treating the area south of the Garlock Fault separately.
- There is no improvement in the gold classification results obtained by treating the area south of the Garlock Fault separately.
- The effect of the geochemical variables is indefinite for the hydrothermal case. Without the geochemical variables a slightly higher percentage of occurrence cells is correctly classified than with the geochemical variables, but much more of the area is classified with high potential. Thus, the "high potential" ratio is lower without the geochemical variables than with the geochemical variables.
- The geochemical variables do not improve the gold classification.

The second measure of the efficiency of DFA is to see how many known occurrences are predicted to have low potential. (This test is performed on all occurrences of a given commodity. The previous test was for occurrence cells only. The distinction arises from the fact that one occurrence cell could contain several occurrences.) This test was performed for two definitioins of low potential.

First, any cell with a probability of correct classification in the occurrence category of 25 percent or less was considered to have low potential. The results are shown in Table C - 7. In each case, although a large percentage of the CDCA is classified as low potential (between 30 and 45 percent) a very low percentage of known deposits are in those areas. Furthermore, by far the predominant number of deposits in those areas never reported any production (production categories 0 or 1).

For the second definition, any cell with a probability of 50 percent or less was defined to have low potential. Those results are shown in Table C - 8. Once again, the observation holds. Despite the fact that three - quarters of the area is classified as having low potential, less than 40 percent of the known deposits occur in those low potential areas, and of these, approximately 80 percent never reported any production. This test, too, is strong support for the discrimination ability of DFA.

TABLE C - 7

DFA Results
Known Deposits In Low Probability (25 Percent)[b] Cells

Case	Total Number Of Occurrences	Number of Known Deposits In Low Probability Cells							Percent Of CDCA Classified Low Probability[b]
		Production Category[a]							
		0	1	2	3	4	Total	Percentage	
Copper, Lead, Silver, Zinc:									
All Areas	509	18	20	7	1	0	46	9	38.0
South Areas	363	14	24	4	0	0	42	12	44.4
South Areas, No Geochemical	363	11	13	2	0	0	26	7	28.8
Gold[c]:									
All Areas	454	6	9	0	0	1	16	4	29.5
South Areas	366	13	14	2	1	0	30	8	41.2
South Areas, No Geochemical	366	11	8	0	0	0	19	5	30.2

(a) - Production Categories (see p. 38 for definition of dollar values)

0 = Occurrence
1 = Workings, but no production
2 = Production under $50,000
3 = Production between $50,000 and $500,000
4 = Production over $500,000

(b) - 25 percent or less probability of correct classification in the occurrence category

(c) - Not including placer deposits

TABLE C - 8

DFA Results
Known Deposits In Low Probability (50 Percent)[b] Cells

Case	Total Number Of Occurrences	Number of Known Deposits In Low Probability Cells							Percent Of CDCA Classified Low Probability[b]
		Production Category[a]					Total	Percentage	
		0	1	2	3	4			
Copper, Lead, Silver, Zinc:									
All Areas	509	58	96	36	7	1	198	39	76.0
South Areas	363	39	83	20	1	0	143	39	76.2
South Areas, No Geochemical	363	44	75	23	2	1	145	40	70.8
Gold[c]:									
All Areas	454	47	68	24	4	1	144	32	70.9
South Areas	366	43	73	21	7	0	144	39	76.1
South Areas, No Geochemical	366	39	72	23	7	0	141	39	76.0

(a) - Production Categories (see p. 38 for definition of dollar values)

0 = Occurrence
1 = Workings, but no production
2 = Production under $50,000
3 = Production between $50,000 and $500,000
4 = Production over $500,000

(b) - 50 percent or less probability of correct classification in the occurrence category

(c) - Not including placer deposits

Tables C - 7 and C - 8 also indicate that, though the results of all cases are good:

- There is no improvement in the classifications of the hydrothermal or gold cases achieved by treating areas south of the Garlock Fault separately.

- The geochemical variables do not improve the classification results for either the gold or hydrothermal cases.

Table C - 9 shows the variables that provide most of the discrimination for each of the six cases. Table C - 9 shows that the geochemical variables are inconsistent in distinguishing mineral potential (e.g., in the different gold cases, different geochemical variables are selected), which indicates that relationships found among the geochemical data and occurrences are coincidental.

The principal conclusion derived from Tables C - 6, C - 7, C - 8 and C - 9 is that the geochemical data do not improve the DFA results for the gold or hydrothermal cases. This does not mean that geochemical sampling data could not improve the results or that the data are bad, only that the sampling data available are insufficient. Two probable reasons for this condition are:

- The low density of sampling points.
- The limited area over which samples were taken.

Samples were taken from four general areas covering about 50 percent of the CDCA. This restricted the number of occurrence cells upon which a discriminant function could be based. Moreover, interpolation of the geochemical sample data from an average 10 - km spacing to 4 - km cells may be stretching the information content of the data.

3.6 VARIABLES USED FOR FINAL DFA

As a result of the eliminations and combinations discussed above, the original 94 variables were reduced to 24 variable sets. The composition of these variable sets is shown in Table C - 10.

TABLE C - 9

Variables Selected By DFA

Variable Components			Variables Selected For Discrimination(1)					
Vari-able Set	Variable Number	Description	Hydro-thermal All Areas	Hydro-thermal South Areas	Hydro-thermal No Geo-chemical	Gold All Areas	Gold South Areas	Gold No Geo-chemical variable
1.	1.	Precambrian granitic rocks.						
2.	2.	Cambrian metamorphic rocks.	+2	+3	+1	+1	+5	+2
	6.	Pre-Cretaceous metasedimentary rocks and pre-Cretaceous metamorphic rocks.						
	7.	Paleozoic and Precambrian metavolcanic rocks.						
	9.	Pre-Cretaceous metavolcanic rocks (If age cannot be established other than pre-Cretaceous).						
3.	3.	Cambrian and late Precambrian sedimentary rocks.			+4			-2
	4.	Ordovician through Mississippian marine sedimentary rocks.						
	5.	Pennsylvanian through Permian marine sedimentary rocks.						
	8.	Triassic-Jurassic marine sediments.						
4.	10.	Mesozoic basic intrusives.	+4	+2	+2	+3	+1	+1
5.	11.	Mesozoic granitic intrusives and pre-Cenozoic granitic and metamorphic rocks.	+1	+4	+3	+2		+4
	14.	Tertiary igneous intrusives (hypabyssal).						
6.	13.	Tertiary sediments (marine and non-marine).						
7.	12.	Eolian deposits.				-1	-2	-1
	16.	Quaternary sediments.						
8.	15.	Tertiary volcanics.						-4
	17.	Quaternary volcanics.						
9.	19.	Length of contact between Precambrian granitic rocks (1) and Precambrian metamorphic rocks (2).						
10.	20.	Length of contact between Mesozoic granitic intrusives and pre-Cenozoic granitic and metamorphic rocks (11), and either Ordovician through Mississippian marine sedimentary rocks (4), or Pennsylvanian through Permian marine sedimentary rocks (5).				-4		-5
	21.	Length of contact between Mesozoic granitic intrusions and pre-Cenozoic granitic and metamorphic rocks (11) and Triassic-Jurassic marine sediments (8).						
11.	22.	Length of contact between Tertiary igneous intrusives (14) and Precambrian granitic rocks (1).						-3
	23.	Length of contact between Tertiary igneous Intrusives (14) and Precambrian metamorphic rocks (2).						
	24.	Length of contact between Tertiary igneous Intrusives (14) and Cambrian and late Precambrian sedimentary rocks (3).						
	25.	Length of contact between Tertiary igneous intrusives (14) and Ordovician through Mississippian marine sedimentary rocks (4).						
	26.	Length of contact between Tertiary igneous intrusives (14) and Pennsylvanian through permian marine sedimentary rocks (5).						
	27.	Length of contact between Tertiary igneous intrusives (14) and pre-Cretaceous metasedimentary rocks and pre-Cretaceous metamorphic rocks (6).						
	28.	Length of contact between Tertiary igneous intrusives (14) and Paleozoic and precambrian metavolcanic rocks (7).						
	29.	Length of contact between Tertiary igneous Intrusives (14) and Triassic-Jurassic marine sediments (8).						
	30.	Length of contact between Tertiary igneous Intrusives (14) and pre-Cretaceous metavolcanic rocks.						
	31.	Length of contact between Tertiary igneous intrusives (14) and Mesozoic basic intrusives (10).						
	32.	Length of contact between Tertiary igneous intrusives (14) and Mesozoic granitic intrusives and pre-Cenozoic granitic and metamorphic rocks (11).						
	33.	Length of contact between Tertiary igneous Intrusives (14) and Tertiary sediments (13).						

TABLE C - 9

Variables Selected By DFA

12.	34. 36.	Length of thrust fouls. Length of non-thrust faults.						
13.	38.	Number of fault intersections.						
14.	41.	Gravity value measured at cell center.			-1			+3
15.	43.	Weighted number of LANDSAT lineaments which intersect in cell.						
16.	66.	Geochemical Variable: Sieved Magnesium						
17.	68.	Geochemical Variable: Sieved Manganese	-5					
18.	72.	Geochemical Variable: Sieved Cobalt					-3	
19.	73.	Geochemical Variable: Sieved Chromium	-2	-5				
20.	74.	Geochemical Variable: Sieved Copper	+5				+4	
21.	75.	Geochemical Variable: Sieved Molybdenum		+5		-2		
22.	76.	Geochemical Variable: Sieved Niobium				-5		
23.	77.	Geochemical Variable: Sieved Lead						
24.	78.	Geochemical Variable: Sieved Vanadium	-1	-1			+3	
25.	79.	Geochemical Variable: Sieved Zinc	+3	-2		+5	-1	
26.	80.	Geochemical Variable: Sieved Cerium	-4					
27.	81.	Geochemical Variable: Heavy Mineral Concentrate Magnesium						
28.	82.	Geochemical Variable: Heavy Mineral Concentrate Titanium		-4				
29.	83.	Geochemical Variable: Heavy Mineral Concentrate Manganese				+4		
30.	84.	Geochemical Variable: Heavy Mineral Concentrate Silver		+1				
31.	86.	Geochemical Variable: Heavy Mineral Concentrate Beryllium						
32.	87.	Geochemical Variable: Heavy Mineral Concentrate Cobalt						
33.	88.	Geochemical Variable: Heavy Mineral Concentrate Chromium				-3	-5	
34.	89.	Geochemical Variable: Heavy Mineral Concentrate Copper		-3				
35.	90.	Geochemical Variable: Heavy Mineral Concentrate Molybdenum					-4	
36.	91.	Geochemical Variable: Heavy Mineral Concentrate Lead						
37.	92.	Geochemical Variable: Heavy Mineral Concentrate Tin						
38.	93.	Geochemical Variable: Heavy Mineral Concentrate Zinc	-3				+2	
39.	95	Geochemical Variable: Heavy Mineral Concentrate Cerium						

(1) (+) indicates correlation with high resource potential, (-) indicates correlation with low resource potential. Numbers indicate rank of correlation: 1 is highest, 2 is next, etc.

4. DISCRIMINANT FUNCTION ANALYSIS RESULTS

Final mineral resource potential classifications were prepared for six categories of commodities using DFA. The commodity categories are:

- Hydrothermal (copper, lead, silver, zinc combined)
- Gold
- Iron
- Manganese
- Tungsten
- Combined Metals

The selection of these commodity categories is discussed in Section 4.1 below. DFA assigned a probability of correct classification in the occurrence category to each commodity category. The cell values were contoured using the SURFACE II graphics package at the Stanford Center for Information Processing and maps were prepared showing contours of 25, 50 and 75 percent probability of correct classification. One map was prepared for each commodity category at 1:250,000 and 1:500,000 scales. These maps at 1:1,000,000 scale are also contained in the pocket at the back of this report.

The Combined Metals map is derived from the other five by assigning each 4 - km by 4 - km cell the highest probability of correct classification of any of the other five cases and contouring the results.

4.1 SELECTION OF COMMODITY CATEGORIES

There are two primary requirements that must be met for DFA to estimate potential for a mineral. The first is the existence of a relationship between the occurrence of the mineral and the independent (measurable) variables (geologic, geophysical, lineament, etc.). The second is that DFA can model that relationship.

The requirement for the existence of a relationship between mineralization and the independent variables that were available to this study almost precludes the consideration of commodity categories such as oil and gas, geothermal, salines and industrial minerals. In general, there is little to tie the occurrence of these commodities to details of regional geology as represented on small scale maps, to gravity data or to lineaments. The potential for geochemical data to define a relationship for these commodities is discussed in Section 3.5. Several tests were made on some of the more abundant of these commodities (e.g., talc, borates, limestone), but the results were not statistically significant. However, relationships were found for the metals.

Since each discriminant function can model only one geologic relationship, it is important that the metals selected to define a commodity category occur in similar geologic environments. Thus, candidates for commodity categories are:

- Gold
- Copper
- Lead, silver, zinc combined
- Iron
- Manganese
- Tungsten
- Iron, manganese combined
- Copper, lead, silver, zinc combined

- Gold, lead, silver, zinc combined
- Gold, copper, lead, silver, zinc combined
- Gold, copper

The second requirement reduces to the requirement that there are a sufficient number of known occurrences of the commodity category in the training set for DFA to derive a relationship. This requirement also precludes consideration of oil and gas (no production in the CDCA) and most of the salines and industrial minerals (few reported occurrences for most commodities).

Each of the 11 commodity categories was tested using DFA (References 92 and 138). The results of the tests were:

- Gold must be considered alone. In all cases in which gold was combined with other metals, the results were less significant. This is probably because the geologic environment of gold deposits is not similar enough to the environment of copper, lead, silver or zinc deposits.

- Copper, lead, silver, zinc combined yields better results than copper alone or lead, silver, zinc combined alone. This is probably because the number of occurrences of both combined is substantially higher than either alone and so the discriminant function is better able to derive a relationship.

- Iron and manganese yield better results alone than combined. This is probably because iron and manganese occur in slightly different geologic environments.

Thus, five cases remain:

- Gold
- Copper, lead, silver, zinc combined
- Iron
- Manganese
- Tungsten

In addition, a Combined Metals case was derived from these five.

4.2 VARIABLES SELECTED BY DFA FOR DISCRIMINATION

The independent variables (geologic, geophysical and lineament) that relate to mineralization and are, therefore, selected by DFA to discriminate between occurrence and non-occurrence categories, vary from commodity category to commodity category. This is expected from the assumption that the commodity categories occur in different geologic environments, and is partial verification of the selection of commodity categories. The variables that provide most of the discrimination for each case are shown in Table C - 10. The numbers in the column of a particular case show the relative importance of the variable: 1 is most important, 2 next, etc. A plus indicates the variable is associated with occurrence of the commodity category. A minus indicates the variable is associated with non - occurrence. Thus, +1 indicates the variable that provides most of the discrimination for mineralization and -1 the variable that provides most of the discrimination for non - occurrence of the particular commodity category.

TABLE C - 10

Variables Selected By DFA

Variable Set	Variable Components		Variables Selected For Discrimination (1)				
	Number	Description	Hydrothermal (2)	Gold	Tungsten	Iron	Manganese
1.	1.	Precambrian granitic rocks.	-3	+5	-3		-3
2.	2.	Cambrian metamorphic rocks.	+1	+1	+4	+2	
	6.	Pre-Cretaceous metasedimentary rocks and pre-Cretaceous metamorphic rocks.					
	7.	Paleozoic and Precambrian metavolcanic rocks.					
	9.	Pre-Cretaceous metavolcanic rocks (if age cannot be established other than pre-Cretaceous).					
3.	3.	Cambrian and late Precambrian sedimentary rocks.	+4				
	4.	Ordovician through Mississippian marine sedimentary rocks.					
	5.	Pennsylvanian through Permian marine sedimentary rocks.					
	8.	Triassic-Jurassic marine sediments.					
4.	10.	Mesozoic basic intrusives.	+3	+3	+3	-1	+3
5.	11.	Mesozoic granitic intrusives and pre-Cenozoic granitic and metamorphic rocks.		+2	+1	+3	
	14.	Tertiary igneous intrusives (hypabyssal).					
6.	13.	Tertiary sediments (marine and non-marine).		-2		-4	
7.	12.	Eolian deposits.	-5	-5		-3	
	16.	Quaternary sediments.					
8.	15.	Tertiary volcanics.	-1	-1			-1
	17.	Quaternary volcanics.					
9.	19.	Length of contact between Precambrian granitic rocks (1) and Precambrian metamorphic rocks (2).	-4	-4		-5	-4
10.	20.	Length of contact between Mesozoic granitic intrusives and pre-Cenozoic granitic and metamorphic rocks (11), and either Ordovician through Mississippian marine sedimentary rocks (4), or Pennsylvanian through Permian marine sedimentary rocks (5).	+2			-2	
	21.	Length of contact between Mesozoic granitic intrusions and pre-Cenozoic granitic and metamorphic rocks (11) and Triassic-Jurassic marine sediments (8).					
11.	22.	Length of contact between Tertiary igneous intrusives (14) and Precambrian granitic rocks (1).					
	23.	Length of contact between Tertiary igneous intrusives (14) and Precambrian metamorphic rocks (2).					
	24.	Length of contact between Tertiary igneous intrusives (14) and Cambrian and late Precambrian sedimentary rocks (3).					
	25.	Length of contact between Tertiary igneous intrusives (14) and Ordovician through Mississippian marine sedimentary rocks (4).					
	26.	Length of contact between Tertiary igneous intrusives (14) and Pennsylvanian through permian marine sedimentary rocks (5).					
	27.	Length of contact between Tertiary igneous intrusives (14) and pre-Cretaceous metasedimentary rocks and pre-Cretaceous metamorphic rocks (6).					
	28.	Length of contact between Tertiary igneous intrusives (14) and Paleozoic and precambrian metavolcanic rocks (7).					
	29.	Length of contact between Tertiary igneous intrusives (14) and Triassic-Jurassic marine sediments (8).					
	30.	Length of contact between Tertiary igneous intrusives (14) and pre-Cretaceous metavolcanic rocks.					
	31.	Length of contact between Tertiary igneous intrusives (14) and Mesozoic basic intrusives (10).					
	32.	Length of contact between Tertiary igneous intrusives (14) and Mesozoic granitic intrusives and pre-Cenozoic granitic and metamorphic rocks (11).					
	33.	Length of contact between Tertiary Igneous intrusives (14) and Tertiary sediments (13).					
12.	34.	Length of thrust fauls.					
	36.	Length of non-thrust faults.					
13.	38.	Number of fault intersections.				+1	+2
14.	41.	Gravity value measured at cell center.	-2		-1		+1
15.	43.	Weighted number of LANDSAT lineaments which intersect in cell.			-2		-2
16.	46.	Sum of total length of LANDSAT lineaments passing through the cell.					-5
17.	55.	Cumulative length of LANDSAT lineaments passing through the cell for each of 8 azimuth classes within an origin of 15°.			-5		
16.	56.		+5		+2		
17.	57.				+5		
20.	58.					+5	
21.	59.				-4	+4	-5
22.	50.						+4
23.	61.			+4			
24.	62.			-3			

(1) (+) Indicates correlation with high resource potential, (-) indicates correlation with low resource potential, numbers indicate rank of correlations- -1 is highest correlation, 2 is next, etc.

(2) Copper, lead, silver, zinc combined

- APPENDIX D -

DEFINITION OF STATISTICAL TERMS

This appendix presents definitions of some of the statistical terms used in this report.

Mean

A measure of central tendancy for a collection of values, also called the average. It is the sum of all values in the collection divided by the number of values in the collection, so if there are n values, $x_1, x_2, \ldots, x_n$, the mean is defined by:

$$\bar{x} = \frac{\sum_{i=1}^{n} x_i}{n}$$

In this study the means of two collections of values are important. The first collection is the group of discriminant function scores of occurrence cells. Its mean is called the group 1 mean. The second collection is the group of discriminant function scores of the non - occurrence cells. Its mean is called the group 2 mean.

Mode

A measure of central tendancy for a collection of values. It is the value that occurs the greatest number of times in the collection.

Variance

A measure of dispersion of values in a collection about the mean. The larger the variance the more dispersed the data are. The variance is also the standard deviation squared. If the standard deviation is denoted by s, the variance may be denoted by s^2 and, using the notation in the definition of the mean above, is defined by:

$$s^2 = \frac{\sum_{i=1}^{n} (x_i - \bar{x})^2}{n-1}$$

Standard Deviation

See variance above.

Pearson Product Moment Correlation Coefficient

A measurement of the relationship of two variables to one another.

For example, the two variables might be concentrations of copper and concentrations of lead in the sieved geochemical samples. At each sample location, each variable is represented by an observation, its value at the location. The coefficient indicates how observations of each variable at the same sample locations vary with respect to each other. This coefficient ranges in value between -1 and 1. If it is 1, then high observations of one variable correspond exactly to high observations of the other and low observations correspond exactly to low observations. If the coefficient is -1, then high observations of one variable correspond exactly to low observations of the other and vice versa. If the coefficient is 0, then there is no correlation indicated. Coefficients between 0 and 1 indicate partial correlation with higher coefficients indicating greater correlation. Coefficients between 0 and -1 indicate partial negative or inverse correlation.

If the two variables are x and y and there are n observations of each, $x_1, x_2, \ldots, x_n$ and $y_1, y_2, \ldots, y_n$, $\bar{x}$ is the mean of x's and $\bar{y}$ is the mean of the y's, s_x is the standard deviation of the x's and s_y is the standard deviation of the y's, then the Pearson product moment correlation coefficient, C_{xy} is defined by:

$$C_{xy} = \frac{\sum_{i=1}^{n} (x_i - \bar{x})(y_i - \bar{y})}{n s_x s_y}$$

Correlation

See Pearson Product Moment Correlation Coefficient above.

F - test for Significance of Separation Between Two Group Means

A measurement to indicate whether or not two group means represent distinct populations. In this study the populations are the collections of discriminant function scores for the occurrence and non - occurrence cells. For the discriminant function to be statistically significant these collections must be distinct. The F - test checks the assumption that the populations are distinct.

In other words, let P_1 be the population of discriminant function scores of all occurrence cells and P_2 the population of discriminant function scores of all non - occurrence cells. Let the group, $x_1, x_2, \ldots, x_n$, be the discriminant function scores for the n occurrence cells in the training set drawn from P_1, and the group $y_1, y_2, \ldots, y_m$, be the scores for the m non - occurrence cells in the training set drawn from P_2. Then the means of these two groups, $\bar{x}$ and $\bar{y}$, are the group one and group two means. If the discriminant function is valid, then the two populations, P_1 and P_2, should consist of values that are, for the most part, separate. The F - test checks whether or not this is a likely assumption by seeing if the distance (separation) between the two group means is large enough.

The test is performed as follows. Kendall (Reference 97) shows that the statistic

$$F_o = \frac{nm(n+m-k-1)}{(n+m)(n+m-2)k} D^2$$

where k is the number of discriminators (variables) used by the discriminant function and D^2 is the distance between the group means, has very nearly the same distribution as the commonly tabulated function, F (with k and n+m-k-1 degrees of freedom). If F_o is greater than F, the separation is statistically significant.

The function, F, is tabulated for several levels of significance. If F_o is greater than F for a given level of significance, S, it means that the probability that the two populations represented by the group means are distinct is at least S. For this study the 99 percent level of significance was applied. Thus, in cases for which the F - test is significant, the probability is greater than 99 percent that the two populations of discriminant function scores are distinct. If the F - test is not significant then the probability is less than 99 percent that the two populations are distinct.

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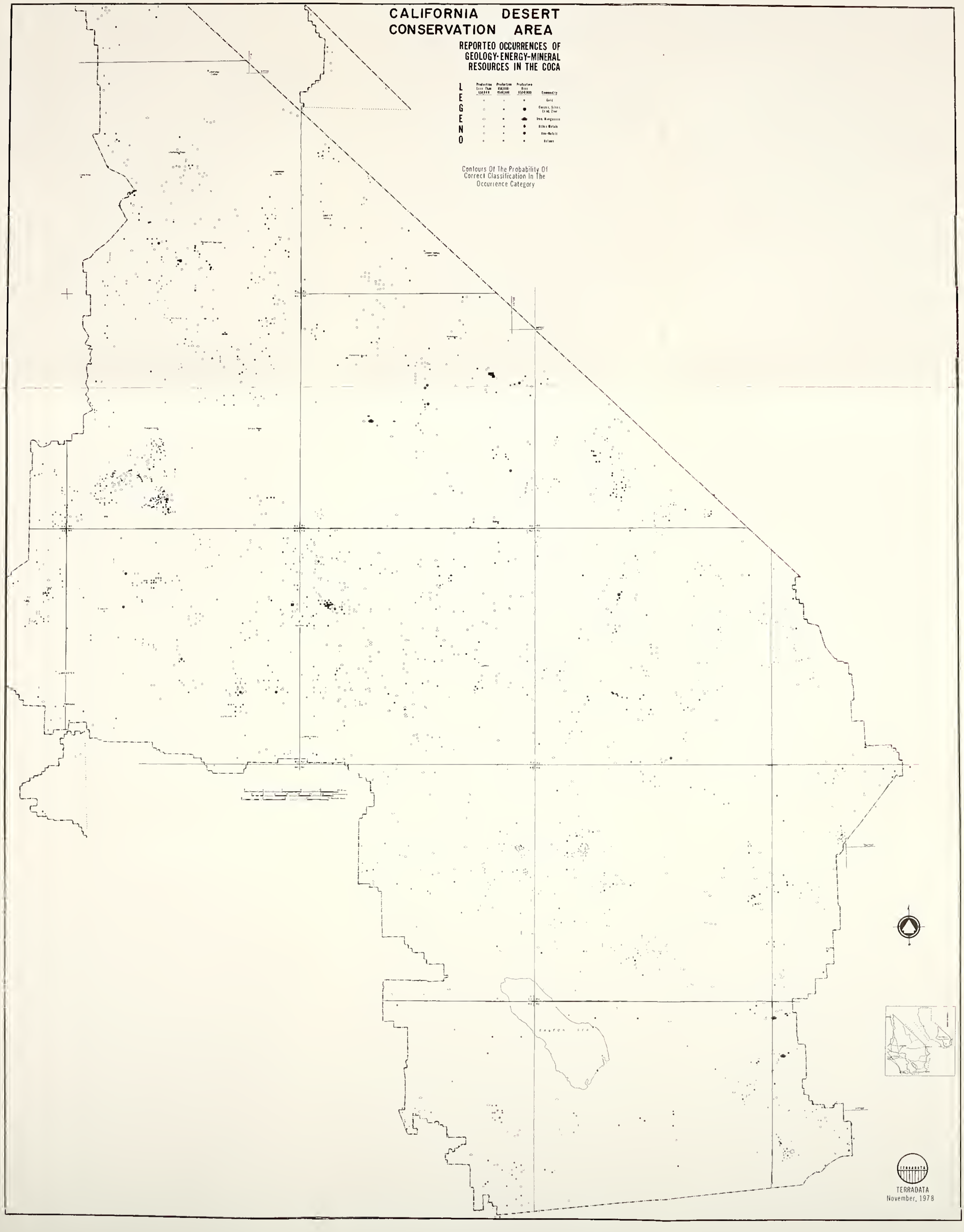


Contours Of The Probability Of Correct Classification In The Occurrence Category

TERRADATA
November, 1978

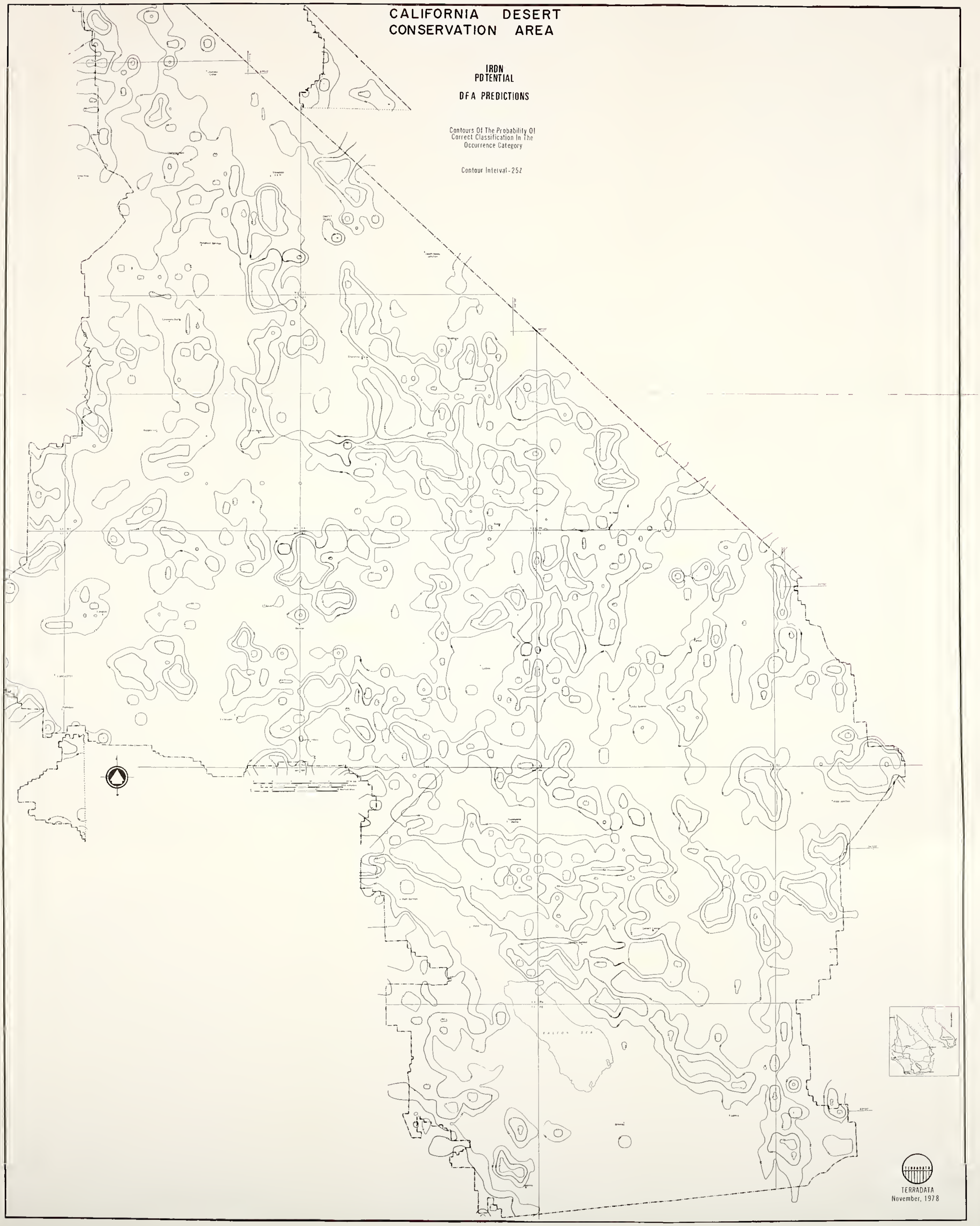
CALIFORNIA DESERT CONSERVATION AREA

IRON POTENTIAL

DFA PREDICTIONS

Contours Of The Probability Of Correct Classification In The Occurrence Category

Contour Interval-25%



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CALIFORNIA DESERT CONSERVATION AREA

COPPER·LEAD·SILVER·ZINC POTENTIAL

DFA PREDICTIONS

Contours Of The Probability Of Correct Classification In The Occurrence Category

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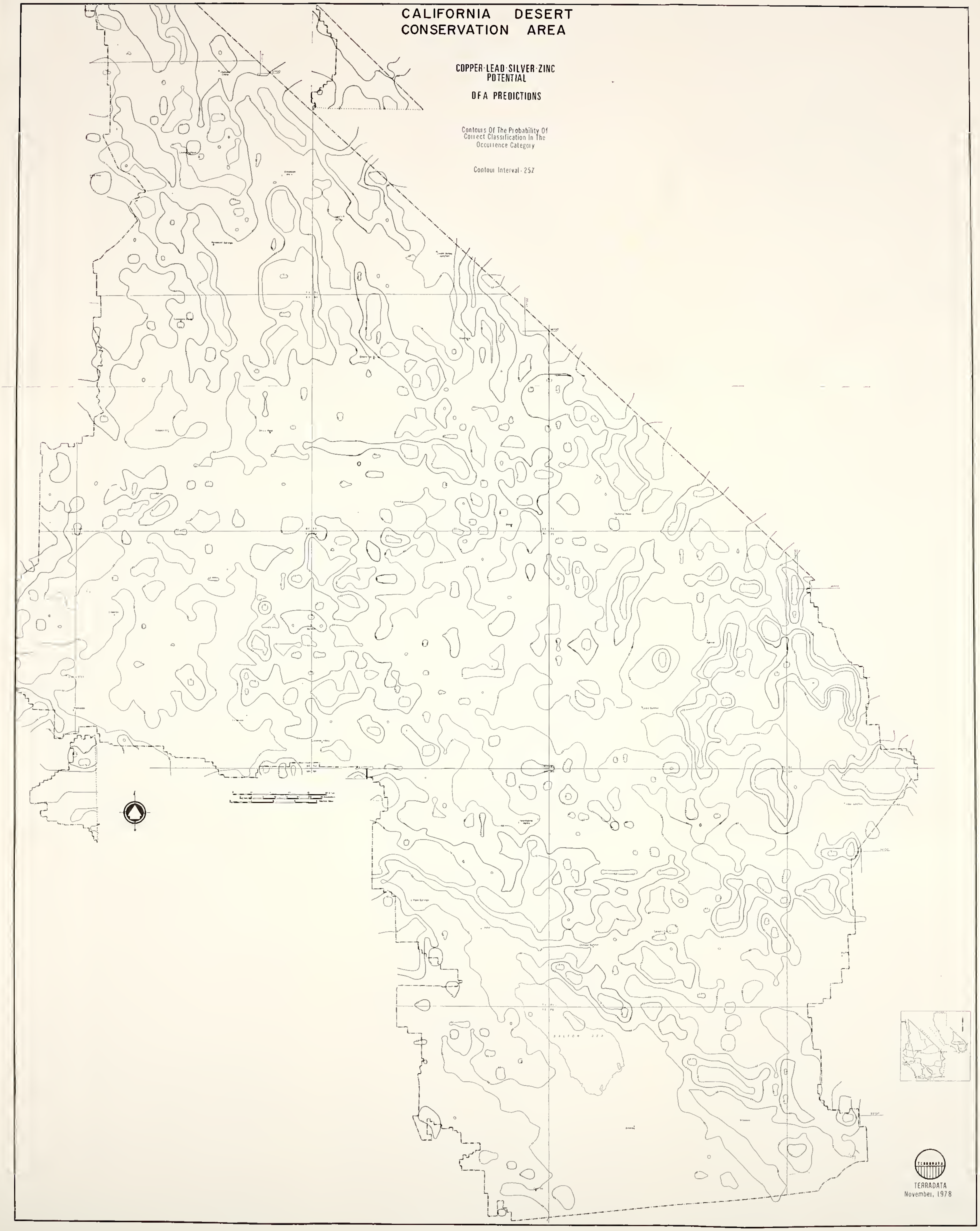

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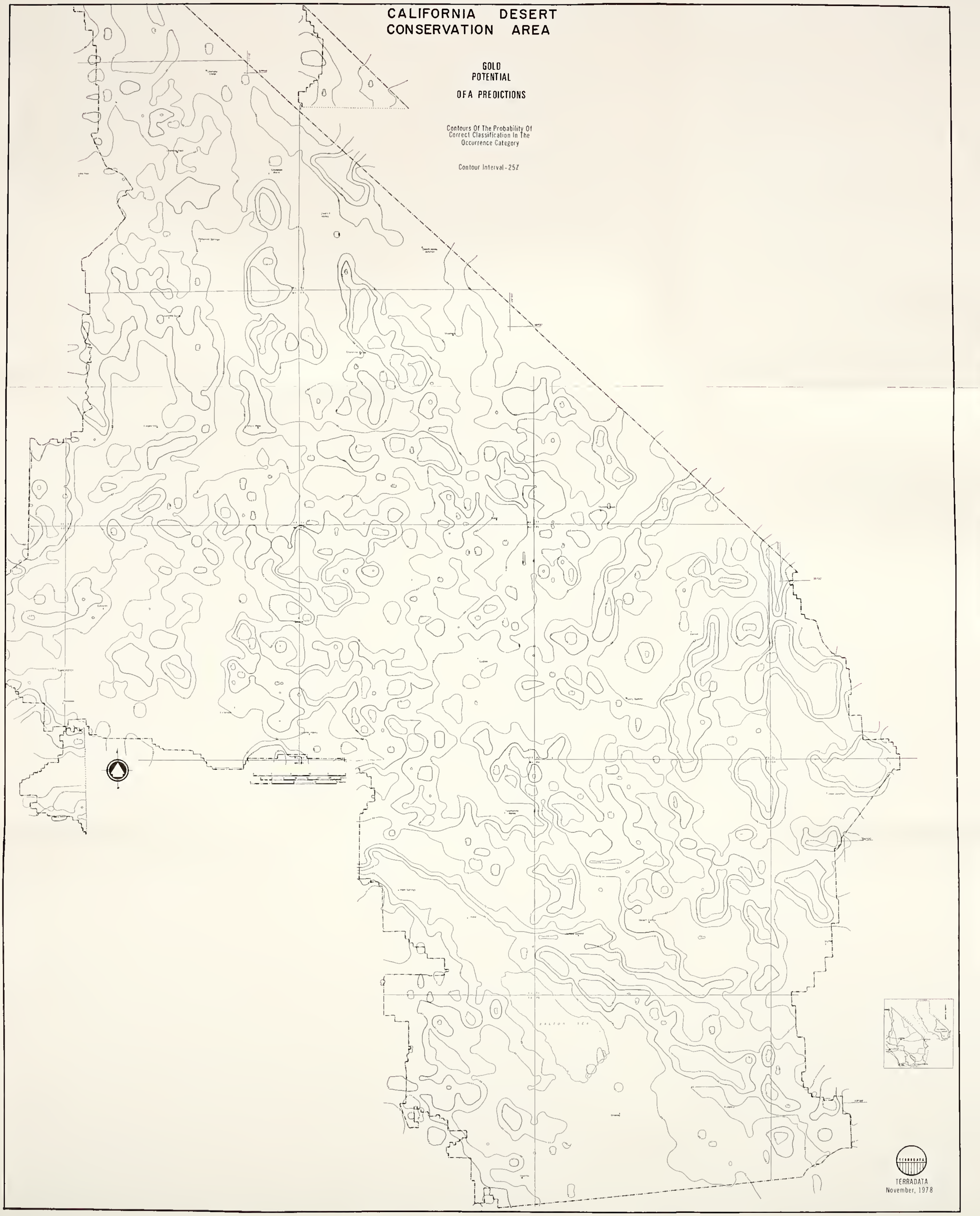
GOLD POTENTIAL

DFA PREDICTIONS

Contours Of The Probability Of Correct Classification In The Occurrence Category

Contour Interval-25%



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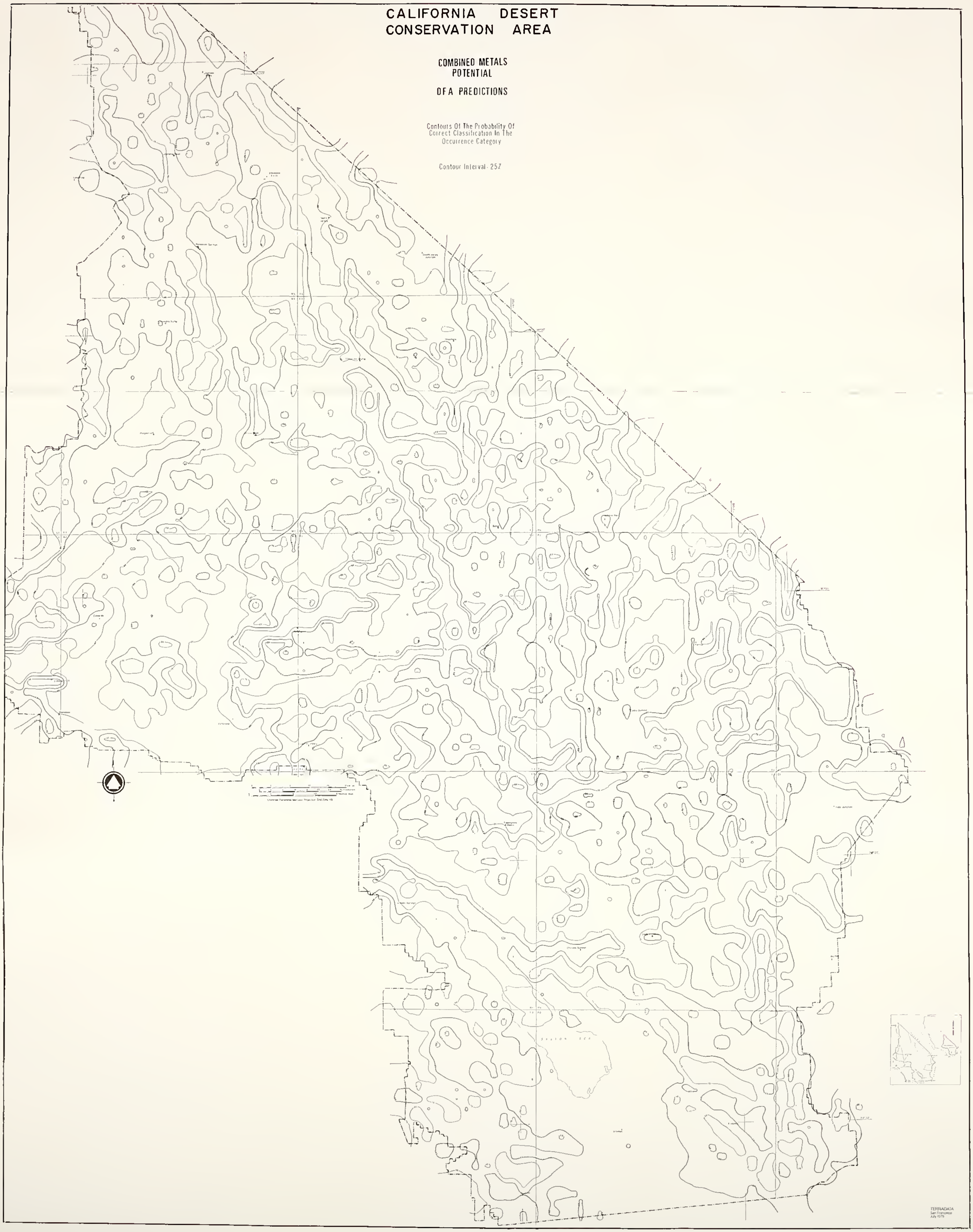
CALIFORNIA DESERT CONSERVATION AREA

COMBINED METALS POTENTIAL

DFA PREDICTIONS

Contours Of The Probability Of
Correct Classification In The
Occurrence Category

Contour Interval - 25%



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